The Development of Norm-Based Coding and Category-Specific Face Prototypes: An Examination of 5- and 8-Year-Olds' Face Space

by

Lindsey A. Short

A thesis submitted in partial fulfillment
of the requirements for the degree
Master of Arts

Department of Psychology
BROCK UNIVERSITY
St. Catharines, Ontario

July 2010

Abstract

The present set of experiments was designed to investigate the organization and refinement of young children's face space. Past research has demonstrated that adults encode individual faces in reference to a distinct face prototype that represents the average of all faces ever encountered. The prototype is not a static abstracted norm but rather a malleable face average that is continuously updated by experience (Valentine, 1991); for example, following prolonged viewing of faces with compressed features (a technique referred to as adaptation), adults rate similarly distorted faces as more normal and more attractive (simple attractiveness aftereffects). Recent studies have shown that adults possess category-specific face prototypes (e.g., based on race, sex). After viewing faces from two categories (e.g., Caucasian/Chinese) that are distorted in opposite directions, adults' attractiveness ratings simultaneously shift in opposite directions (opposing aftereffects).

The current series of studies used a child-friendly method to examine whether, like adults, 5- and 8-year-old children show evidence for category-contingent opposing aftereffects. Participants were shown a computerized storybook in which Caucasian and Chinese children's faces were distorted in opposite directions (expanded and compressed). Both before and after adaptation (i.e., reading the storybook), participants judged the normality/attractiveness of a small number of expanded, compressed, and undistorted Caucasian and Chinese faces. The method was first validated by testing adults (Experiment 1) and was then refined in order to test 8- (Experiment 2) and 5-year-old (Experiment 4a) children. Five-year-olds (our youngest age group) were also tested in

a simple aftereffects paradigm (Experiment 3) and with male and female faces distorted in opposite directions (Experiment 4b).

The current research is the first to demonstrate evidence for simple attractiveness aftereffects in children as young as 5, thereby indicating that similar to adults, 5-year-olds utilize norm-based coding. Furthermore, this research provides evidence for race-contingent opposing aftereffects in both 5- and 8-year-olds; however, the opposing aftereffects demonstrated by 5-year-olds were driven largely by simple aftereffects for Caucasian faces. The lack of simple aftereffects for Chinese faces in 5-year-olds may be reflective of young children's limited experience with other-race faces and suggests that children's face space undergoes a period of increasing differentiation over time with respect to race. Lastly, we found no evidence for sex-contingent opposing aftereffects in 5-year-olds, which suggests that young children do not rely on a fully adult-like face space even for highly salient face categories (i.e., male/female) with which they have comparable levels of experience.

Acknowledgements

First, I would like to thank my supervisor, Dr. Cathy Mondloch, for her guidance, expertise, and insight throughout the completion of this thesis. Her continuous support and wonderful sense of humor helped make this an enjoyable process and her frequent feedback was insightful and crucial to the success of this project. Special thanks also goes to Alexandra Hatry, who designed and tested participants on the adult and 8-year-old storybooks, and to my committee members, Dorothy Markiewicz and Kang Lee, who provided valuable feedback throughout the completion of this project.

Second, I would like to thank the members of the Infant and Child Development lab- Danielle Longfield, Kevin Proulx, Jasmine Mian, and Lindsay Meldrum- for their daily support, friendship, and humor. They are a great team to work with and made each day in the lab a fun experience. Special thanks goes to my labmate, Danielle Longfield, who provided so much encouragement and was always there for me at all hours of the day.

Table of Contents

Figures

Appendix

The Development of Norm-Based Coding and Category-Specific Face Prototypes: An Examination of 5- and 8-Year-Olds' Face Space

Despite the homogeneity of facial structure, adults are capable of recognizing and discriminating between hundreds of human faces and exhibit little difficulty detecting subtle featural and configural cues to identity (Freire, Lee, & Symons, 2000; for a review see Maurer, Le Grand, & Mondloch, 2002). They process faces holistically rather than parsing a face into individual features (Carey & Diamond, 1994; Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987), and their expertise is considerably influenced by experience – recognition accuracy is greatest for upright human faces of an individual's own race (Collishaw & Hole, 2000; Meissner & Brigham, 2001; Rhodes, Hayward, & Winkler, 2006). Adults' expertise in face processing has been attributed to norm-based coding, a process by which individual faces are encoded relative to a face prototype (Valentine, 1991). Recent studies (e.g., Jaquet, Rhodes, & Hayward, 2008) have demonstrated that rather than coding all faces in reference to a single face prototype, adults possess multiple prototypes that code for the various face categories encountered in the environment (e.g., race, sex). The overarching goal of the current research was to examine the development of norm-based coding, with emphasis on the development of category-specific face prototypes in young children.

Norm-Based Face Coding in Adulthood

Adults' face prototype represents a norm that has been abstracted from all faces previously encountered in the environment. According to Valentine's (1991) norm-based coding model, individual faces differ on a variety of dimensions (e.g., distance between the eyes), and each dimension is represented as a unique vector in a multidimensional face space. Individual faces are represented as single points within this face space. The density of points is greatest near the prototype and decreases as the distance from the average face increases; thus the farther a face is from the prototype, the more distinctive it appears. Valentine's model has been supported by studies indicating that caricatures are rated as more distinctive than unaltered images and that recognition accuracy is greater for caricatures than for veridical line drawings (Lee, Byatt, & Rhodes, 2000; Rhodes, Brennan, & Carey, 1987; Rhodes & Tremewan, 1994). In addition to appearing more typical and less distinctive, faces that are close to the prototype are rated as more attractive and more normal than faces that are distant (Langlois & Roggman, 1990; Potter & Corneille, 2008; Rhodes, Sumich, & Byatt, 1999; Rhodes & Tremewan, 1996; Valentine, Darling, & Donnelly, 2004).

The prototype is not a static abstracted norm but rather a malleable face "average" that is continuously updated by experience. One way in which norm-based coding and the plasticity of the face prototype have been investigated is through experimental adaptation and aftereffects. Aftereffects have been reported across a wide variety of visual domains and are evident in any situation in which an individual's perception of a given stimulus is affected by exposure to a previously shown stimulus. For example, following prolonged exposure to the image of a waterfall, a stationary pattern appears to move upward (Frisby, 1980; reviewed in Leopold & Bondar, 2005), and following prolonged exposure to a red square, a green square appears to emerge on top of a white background (Hering, 1964). Adaptation aftereffects are presumed to reflect reduced neural activation following repetitive stimulation (Ibbotson, 2005) and are indicative of our nervous system's attempt to restore balance in an ever-changing external environment (Webster, 2004).

Repeated exposure to faces distorted in a similar direction (e.g., with compressed features) produces a temporary shift in the prototype, which subsequently alters perceived attractiveness such that unaltered faces appear distorted in the opposite direction while distorted faces appear more attractive (Rhodes, Jeffery, Watson, Clifford, & Nakayama, 2003; Webster & MacLin, 1999). For example, following exposure to a series of faces with expanded features, the prototype moves toward the expanded side of the previous norm. Thus expanded faces are closer to the average and unaltered faces are clustered around the opposite (i.e., the compressed) side. Following adaptation to a single face category (e.g., female), previously ambiguous faces appear to take on the opposite features and belong to the opponent face category (i.e., male) (Webster, Kaping, Mizokami, & Dumahel, 2004). Such aftereffects have been found not only for the perception of attractiveness and sex but also for the perception of identity (Anderson & Wilson, 2005; Leopold, O'Toole, Vetter, & Blanz, 2001; Rhodes & Jeffery, 2006), race, and emotional expression (Webster et al., 2004).

Category-Specific Face Prototypes in Adults

In addition to providing evidence for the malleability of the face prototype, experimental adaptation has been used to examine the potential existence of multiple face prototypes that code for various face categories. In Valentine's (1991) initial conceptualization of face space, faces are encoded relative to a single prototype that represents the overall central tendency of all faces ever encountered by an individual. However, given the variety of ways in which individuals can categorize faces, it seems likely that separable prototypes exist which represent the different face categories encountered in the environment (Cosmides, Tooby, & Kurzban, 2003). Support for such a framework stems from simultaneous adaptation studies that have yielded evidence for category-contingent opposing aftereffects. Following adaptation to two face categories that are distorted in opposite directions (e.g., compressed Chinese faces and expanded Caucasian faces), adults' judgments of attractiveness and normality shift in opposite directions (Jaquet et al., 2008). This shift is possible only if adults possess multiple face prototypes that code for faces from different face categories. In this situation, the prototype for Chinese faces shifts toward compressed faces while the prototype for Caucasian faces simultaneously shifts toward expanded faces following adaptation. Thus the norms for two different face categories are concurrently moving in opposite directions. If adults were processing the two face categories using a single prototype, the two distortions would cancel each other out and opposing aftereffects would not emerge. Opposing aftereffects have been found for faces that differ according to race (Jaquet et al., 2008; Little, DeBruine, Jones, & Waitt, 2008), sex (Jaquet & Rhodes, 2008; Little, DeBruine, & Jones, 2005), orientation (Rhodes et al., 2004), age, and species (Little et al., 2008). The simultaneous shift in attractiveness/normality judgments indicates that the coding mechanisms responsible for the two face categories are dissociable from one another and not entirely overlapping (Jaquet & Rhodes, 2008). Jaquet et al. have suggested that such dissociable coding mechanisms may be reflective of underlying neural populations that are specialized for different categories of faces.

Opposing aftereffects appear to be based on face categories rather than structural differences per se. The results of two studies show that opposing aftereffects occur when the oppositely distorted faces belong to two different categories (e.g., male versus female; Caucasian versus Chinese) but are mitigated or absent when faces in the two categories differ by the same amount physically but belong to the same social/perceptual category (e.g., female versus hyper-female; Chinese versus Super-Chinese)[1] (Bestelmeyer et al., 2008; Jaquet, Rhodes, & Hayward, 2007).

The Development of Norm-Based Coding

Even young children demonstrate several characteristics of adult-like face processing. They process faces holistically (Carey & Diamond, 1994; de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007; Pellicano & Rhodes, 2003; Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998), are more accurate at recognizing upright versus inverted faces (Pellicano & Rhodes, 2003) and own- versus other-race faces (Chance, Turner & Goldstein, 1982; Sangrigoli & de Schonen, 2004a) and show sensitivity to both featural and relational (e.g., the spacing between features) cues to facial identity (Diamond & Carey, 1977; Freire & Lee, 2001; McKone & Boyer, 2006; Mondloch, Le Grand, & Maurer, 2002). Nonetheless, they continue to make more errors than adults on a variety of face perception tasks until mid-adolescence (Bruce et al., 2000; Mondloch, Dobson, Parsons, & Maurer, 2004). This slow development cannot be attributed solely to gains in memory and attention (Mondloch et al., 2004; Mondloch, Geldart, Maurer, & Le Grand, 2003; but see Crookes & McKone, 2009). Even when such cognitive demands are controlled for, children exhibit a number of limitations in their ability to recognize faces; they are less sensitive than adults to differences among faces in the spacing of features (Freire & Lee, 2001; Mondloch et al., 2002; Mondloch & Thomson, 2008) and are particularly susceptible to

[1] Super-Chinese, Super-Caucasian, and hyper-female faces were made by caricaturizing faces from each of these three categories so as to exaggerate race- and sex-specifying characteristics.

distraction by external paraphernalia (Diamond & Carey, 1977; Freire & Lee, 2001). Furthermore, they require greater differences among faces in order to consistently rate unaltered faces as more attractive than faces with compressed or expanded features (Anzures, Mondloch, & Lackner, 2009) and are generally less sensitive than adults to distortions that increase the grotesqueness of a face (Mondloch et al., 2004; see McKone & Boyer, 2006 for a similar pattern of results for ratings of distinctiveness).

Rhodes et al. (2005) have suggested that a potential explanation for the slow development of adult-like expertise in face processing is that children rely less than adults on norm-based coding of faces. Children may differ from adults in several ways: their representation of the prototype(s), the number of dimensions in their face space, the dimensions on which they rely, or the extent to which they are sensitive to differences within the dimensions of face space. There is some evidence that even infants engage in norm-based coding. Newborns look longer toward faces that adults rate as attractive (Slater et al., 1998), and by 3 months, infants are capable of forming a face prototype that represents the average of a set of faces (de Haan, Johnson, Maurer, & Perrett, 2001) and demonstrate a preference for averaged female child faces over averaged male child faces, which suggests that infants' increased familiarity and experience with female adult faces generalizes to prototypical female children's faces (Quinn et al., in press). Furthermore, by 3 years of age, children rate faces that are similar to their prototype as most attractive (Cooper, Geldart, Mondloch, & Maurer, 2006). Despite this evidence, only two studies have examined simple aftereffects in children and the underlying organization of children's face space. Nishimura, Maurer, Jeffery, Pellicano, and Rhodes (2008) examined simple identity aftereffects in 8-year-olds and adults and demonstrated that both age groups exhibit a comparable response pattern consistent with norm-based coding. Following adaptation to one identity (e.g., anti-Dan), a previously ambiguous face is perceived as the computationally opposite identity (i.e., Dan). Of most importance for the current set of studies, Anzures et al. (2009) provided the first evidence of attractiveness aftereffects in 8-year-old children. Children read a computerized storybook in which the features of every face had been compressed inward or expanded outward. Following adaptation, children's attractiveness preferences shifted toward the distortion to which they had been exposed.

Although the aforementioned studies suggest that children as young as 8 utilize norm-based coding, two questions remain unanswered. First, it is unknown whether children of a younger age rely on a face prototype that is continuously updated by experience. To our knowledge, no study has investigated whether children younger than 8 years of age show simple attractiveness aftereffects. Second, it is unknown whether children possess category-specific face prototypes. Children's face space may be less well refined than adults', which may help account for their relative insensitivity to several cues to facial identity (e.g., Freire & Lee, 2001; Gilchrist & McKone, 2003; Mondloch et al., 2002; Mondloch & Thomson, 2008). For example, it may be the case that children rely on a single prototype and its corresponding dimensions when processing faces from different face categories (e.g., Caucasian versus Chinese faces). In contrast, evidence of opposing aftereffects in children would demonstrate that children, like adults, possess multiple face prototypes that code for faces from various face categories. Such evidence would suggest that the organization of children's face space parallels that of adults and would therefore eliminate a potential explanation for the slow development of adult-like expertise in face processing.

In the current study, we focused our investigation on whether children demonstrate evidence for race-contingent opposing aftereffects. Our decision to use race as the primary face category was based on extensive literature suggesting that both adults and children exhibit an own-race recognition advantage (Chance, Turner & Goldstein, 1982; Meissner & Brigham, 2001; Sangrigoli & de Schonen, 2004a) and that sensitivity to own-races faces emerges early in development. Infants demonstrate a preference for own-race faces by 3 months of age (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005) and by 9 months of age exhibit an adult-like perceptual asymmetry in which an other-race face among own-races faces pops out more than an own-race face among other-race faces (Hayden, Bhatt, Zieber, & Kangas, 2009). Furthermore, a recognition advantage for own- versus other-race faces begins to emerge by 6 months of age and is fully present in infants as young as 9 months (Kelly et al., 2007; Sangrigoli & de Schonen, 2004b). Such research suggests that race is a salient face category for even young children and thus is a suitable category for exploring the development of dissociable face prototypes.

The Present Study

To determine whether children possess category-specific face prototypes, we designed and validated a novel child-friendly method for eliciting race-contingent opposing aftereffects. In all past studies investigating opposing aftereffects, adults passively viewed a series of distorted faces for a specified period of time and judged facial attractiveness/normality both before and after this viewing period. During test trials, they have been asked to judge between 10 and 272 faces (Jaquet et al., 2007; Jaquet et al., 2008; Jeffery, Rhodes, & Busey, 2007; Little et al., 2005; Little et al., 2008; Rhodes et al., 2004). In order to maintain children's attention during adaptation, we created a computerized storybook in which Caucasian and Chinese children's faces were distorted in opposite directions (expanded and compressed). The storybook was about two birthday parties, one of which was attended only by Caucasian children and the other of which was attended only by Chinese children. Both before and after adaptation (i.e., reading the storybook), participants were asked to judge the normality/attractiveness of a small number of expanded, compressed, and undistorted Caucasian and Chinese faces. We validated our method by testing adults (Experiment 1) and then refined it (see below) in order to test 8-year-old children (Experiment 2). Opposing aftereffects would be evident if participants' attractiveness judgments simultaneously shifted in opposite directions for the two face categories.

In order to examine whether children younger than 8 years of age rely on a face prototype that is continuously updated by experience, in Experiment 3 we tested 5-year-old children on a modified version of the task employed by Anzures et al. (2009). Only Caucasian faces were included in the storybook. Half of the children were adapted to expanded Caucasian faces and the other half were adapted to compressed Caucasian faces. Simple attractiveness aftereffects would provide evidence that, like adults and 8-year-olds, 5-year-olds rely on a prototype that is continuously updated as a result of face experience. This task also served a second function. Before testing 5-year-olds in an opposing aftereffects task, we needed to refine our testing protocol such that failure to find opposing attractiveness aftereffects could not be attributed to a flawed method incapable of eliciting even simple aftereffects. Finally, we tested 5-year-olds (our youngest age group) in two opposing aftereffects tasks in which Caucasian and Chinese faces (Experiment 4a) and male and female faces (Experiment 4b) were distorted in opposite directions. Sex is a highly salient social category for young children (Martin & Halverson, 1981) and we wanted to test 5-year-olds under the conditions in which they would be most likely to demonstrate opposing aftereffects.

One strength of our research design is that the method used to measure opposing aftereffects was refined for each age group because of changes in cognitive ability across the age range of participants that we tested. Although all age groups were adapted to distorted faces with the same method (the storybook), the method used during the pre- and post-adaptation judgment phases varied with age. This practice is not uncommon in developmental research (e.g., Cooper et al., 2006) and ensures that the most sensitive measure of an underlying ability is used for each age group. For each age group we tested opposing attractiveness aftereffects with the same procedure that successfully revealed simple attractiveness aftereffects in previous research (adults and 8-year-olds; Anzures et al., 2009) or in the current set of studies (5-year-olds; Experiment 3). Thus a lack of opposing aftereffects is unlikely the result of our method being inappropriate for the age being tested.

Experiment 1: Race-Contingent Opposing Aftereffects in Adults

As in previous studies investigating opposing aftereffects (e.g., Jaquet & Rhodes, 2008; Jaquet et al., 2008), adults were asked which member of ten face pairs (five Caucasian) appeared more normal both before and after adaptation. Normality judgments (versus attractiveness judgments) were used as past research has suggested that normality judgments may be less influenced by postvisual cognitive processes than attractiveness judgments and therefore provide a "purer" measure of perceptual change. For example, Winkler and Rhodes (2005) demonstrated that exposure to exceptionally wide bodies produced increased normality ratings for wide bodies following adaptation while attractiveness ratings remained the same after adaptation. In the present experiment, one member of each pair had expanded features (+10%) and the other had compressed features (-10%). This is consistent with past research that has demonstrated that testing adults with face pairs consisting of ±10% distortions provides a sensitive measure of the opposing aftereffects elicited during adaptation (e.g., Jaquet & Rhodes, 2008; Jaquet et al., 2007). To make the task child-friendly, adaptation occurred while adults read a 5-minute computerized storybook about two birthday parties. The storybook was designed to capture children's attention and keep them looking at the screen throughout adaptation. Opposing aftereffects would be evident if following adaptation, the number of trials in which the expanded member of each pair is selected as most normal increased more for the race of face that was expanded during adaptation than for the race of face that was compressed. No differences in normality preferences were expected pre-adaptation.

Method

Participants. Twenty-four Caucasian undergraduates from Brock University (20 female; Mean age = 21.5 years, range = 18-27) participated in this experiment and received research credit or a small honorarium. An additional seven participants were tested but excluded from all data analyses because they failed to pass pre-adaptation criterion trials (n = 6) or did not follow task instructions (n = 1). In this and all subsequent opposing aftereffects experiments, half of the participants were adapted to compressed Caucasian and expanded Chinese faces; the other half were adapted to the reverse condition.

Materials. Stimuli consisted of colored photographs of Caucasian and Chinese 4- to 6-year-old children. All faces were distorted using the spherize function in Adobe Photoshop Version 8.0. The experiment consisted of three phases: pre-adaptation normality trials, adaptation, and post-adaptation normality trials. Pre- and post-adaptation stimuli were divided into two sets of 10 face pairs; half of the face pairs in each set were Caucasian and half were Chinese. Each face pair was comprised of two versions of the same identity; one version was expanded (+10%) and the other was compressed (-10%) (see Figure 1a). For each face set, participants viewed three pairs of male faces and two pairs of female faces for one race and three pairs of female faces and two pairs of male faces for the other race; the relative number of male versus female faces for each race was counterbalanced across the two face sets. Face pairs from one set were shown pre-adaptation and face pairs from the other set were shown post-adaptation; the order in which the two sets were presented was counterbalanced across participants and within each set faces appeared in one of two different orders. Faces of twelve different identities (six Caucasian, six Chinese) were used as adaptation stimuli. These faces were presented in the context of a 5-minute computerized storybook in which Caucasian faces were distorted in one direction while Chinese faces were distorted in the opposite direction (±60%) (see Figure 1d). Only one race of face was presented on each page and race of face alternated from page to page.

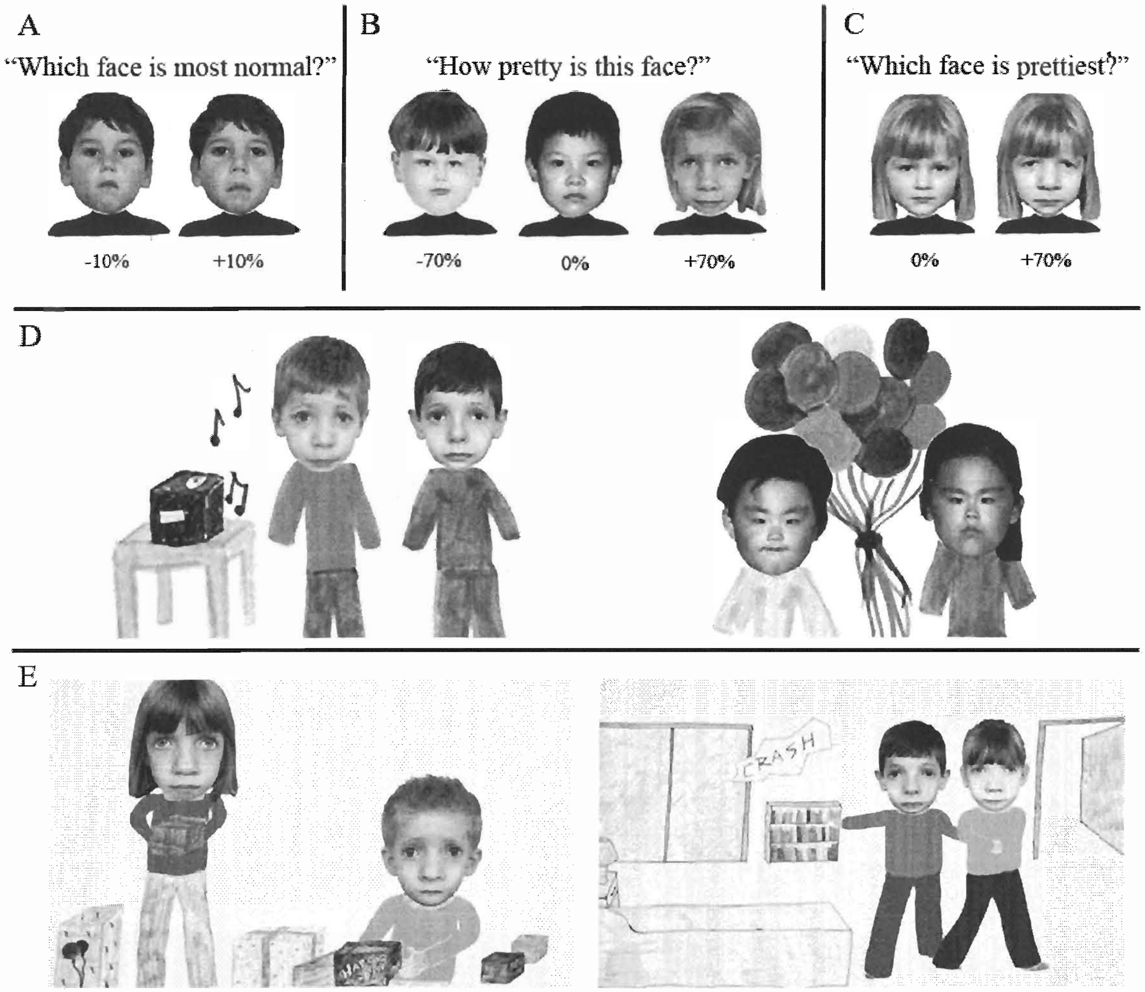

Figure 1. A-C: Face stimuli shown during test phases. Adults indicated which member of each face pair was more normal (A), 8-year-olds rated the attractiveness of individual faces (B), and 5-year-olds indicated which member of each face pair was more attractive (C). Sample pages from the adaptation storybook used for adult participants in Experiment 1 (D) and for 5-year-olds in Experiment 3 (E).

Procedure. In this and all subsequent experiments, the procedure was approved by the Research Ethics Board at Brock University. Upon arrival to the lab, participants were seated approximately 60 cm in front of a 23-inch computer monitor and asked to complete four criterion trials. Participants were shown four pairs of faces (two Caucasian) and asked to select the most normal face within each pair. Pairs consisted of two faces of the same identity; one face was undistorted while the other was either expanded (+20%) or compressed (-20%). Participants viewed a pair with an expanded distortion and a pair with a compressed distortion for each race. In order to be included in the final analysis, participants were required to select the undistorted face in at least three of the four criterion trials. Exclusion was based on the assumption that participants who failed to meet this criterion had either an unusual insensitivity to facial distortions or failed to understand task instructions.

Following the criterion trials, participants were told that they would be shown pairs of brothers and sisters and that their task was to indicate which brother/sister in each pair appeared more normal. Each participant viewed 10 face pairs (five Caucasian and five Chinese). Pairs consisted of two faces of the same identity; one face was expanded (+10%) while the other face was compressed (-10%). The face pairs remained on the screen until participants indicated their response by pointing to the side of the screen on which the normal face appeared.

Once the pre-adaptation trials were completed, participants were read one of two versions of a storybook. The storybook was about two separate birthday parties, one that was attended only by Caucasian children and another that was attended only by Chinese children. Half of the participants were adapted to expanded Caucasian faces (+60%) and compressed Chinese faces (-60%) and the other half were adapted to compressed Caucasian faces and expanded Chinese faces. Each page of the storybook contained between one and seven faces, and the size and location of the faces varied to eliminate low-level retinotopic adaptation. Only one face race was presented on each page and race of face alternated from page to page. Following the storybook, participants were shown an additional 10 face pairs (five Caucasian) and asked to select the most normal face in each pair. In order to maintain adaptation, face pairs remained on the screen for 3 seconds and were then replaced by a blank screen. Furthermore, after each post-adaptation trial two top-up faces were presented, one Caucasian and one Chinese; top-up faces were distorted in a way that was consistent with adaptation (see Rhodes et al., 2003). The first top-up face matched the race of the previous trial and the second top-up face matched the race of the next trial. For example, for participants adapted to compressed Chinese faces and expanded Caucasian faces, after judging a pair of Caucasian faces an expanded Caucasian face was presented, followed by a compressed Chinese face and then a pair of Chinese faces was presented on the next test trial. Top-up faces were paired with a comment designed to encourage participants (e.g., “I think so too!”) and were used to maintain adaptation throughout the post-adaptation judgment trials (see Anzures et al., 2009; Rhodes et al., 2003).

Results and Discussion

For each participant the number of trials on which they selected the expanded face as most normal was calculated for each race pre- and post-adaptation. To determine whether adults showed opposing aftereffects, change scores were calculated by subtracting the number of expanded faces selected as most normal pre-adaptation from the number of expanded faces selected as most normal post-adaptation for both the expanded face race and the compressed face race. For each adaptation condition (compressed/expanded) half of the judgments were from Caucasian faces and half were from Chinese faces, because half of the participants were adapted to compressed Chinese faces and the other half were adapted to compressed Caucasian faces. Because change scores may be influenced by pre-adaptation judgments, we first examined whether the number of expanded faces selected as most normal pre-adaptation differed for the race of face to be expanded versus the race of face to be compressed. A paired-samples *t*-test revealed that there was no difference in the number of expanded faces selected pre-adaptation for the race of face to be expanded ($M = 2.29$, $SE = .29$) and the race of face to be compressed ($M = 2.38$, $SE = .23$), $t(23) = .29$, $p > .70$, two-tailed.

In order to determine whether participants showed opposing aftereffects, we examined whether the change in the number of expanded faces selected as most normal differed between the race of face that was expanded and the race of face that was compressed. As shown in Figure 2a, the number of expanded faces selected as most normal increased more for the race of face that was expanded (Mean change score = .42, $SE = .38$) than for the race of face that was compressed (Mean change score = -.46, $SE = .26$), $t(23) = 2.03$, $p < .05$, one-tailed[2].

In order to determine whether the presence of opposing aftereffects was driven entirely by simple aftereffects for a single race (e.g., for Caucasian faces) or by the combination of simple aftereffects for both races, we examined the data using stimulus

---

[2] In this and all subsequent analyses, one-tailed *t*-tests were performed because adaptation leads to specific predictions about the direction in which attractiveness/normality preferences should shift for each face category.

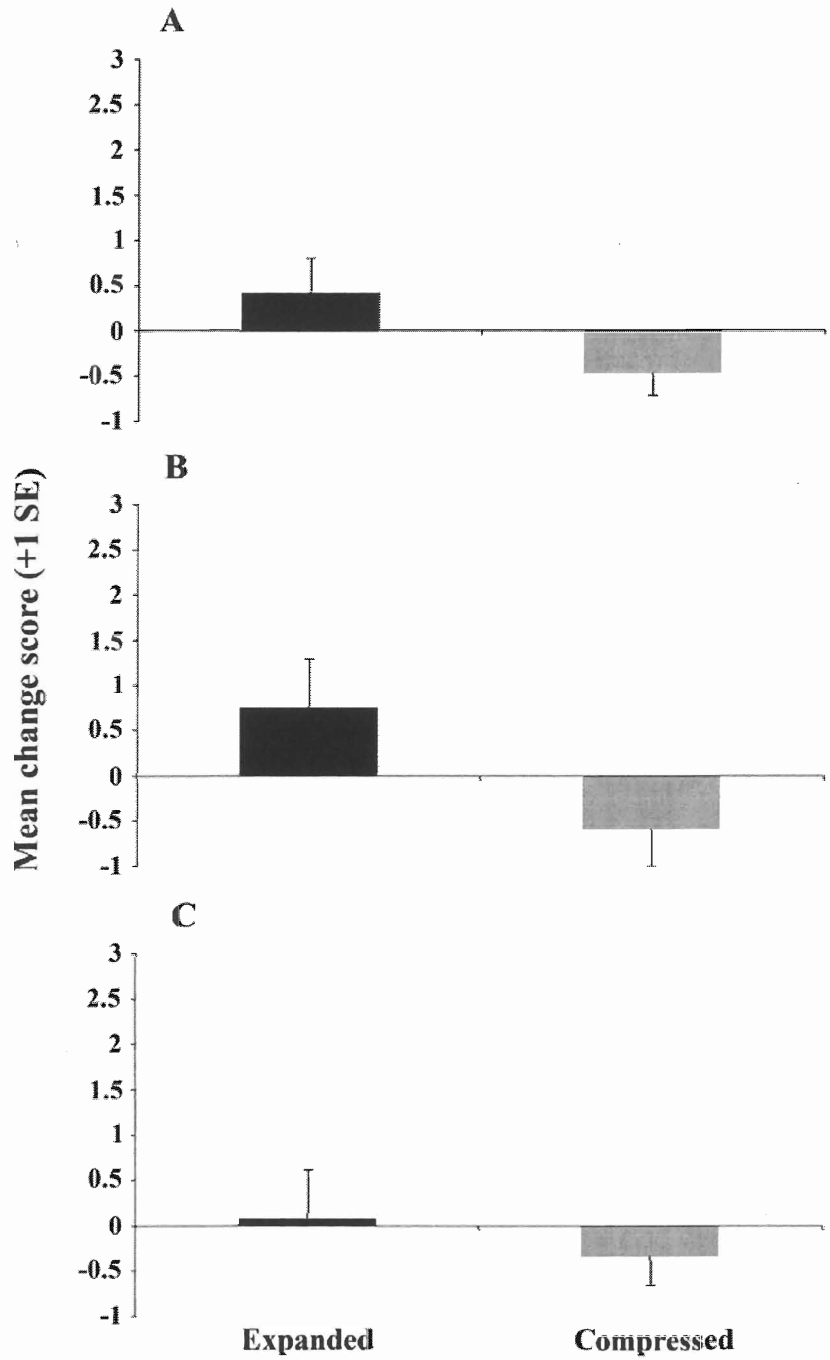

Figure 2. A. Among adults, mean change scores for the race of face that was expanded versus the race of face that was compressed during adaptation. B. For Caucasian test faces, mean change scores for adults adapted to expanded versus compressed Caucasian faces. C. For Chinese test faces, mean change scores for adults adapted to expanded versus compressed Chinese faces.

race as a factor. We first examined whether participants exhibited evidence for simple aftereffects for Caucasian faces. To do so, we compared change scores for the 12 participants adapted to expanded Caucasian faces to change scores for the 12 participants adapted to compressed Caucasian faces. As shown in Figure 2b, the number of expanded Caucasian faces selected as most normal increased more for participants adapted to expanded Caucasian faces (Mean change score = .75, *SE* = .54) than for participants adapted to compressed Caucasian faces (Mean change score = -.58, *SE* = .42), $t(22) = 1.96$, $p < .05$, one-tailed.

To determine whether participants demonstrated evidence for simple aftereffects for Chinese faces, we compared change scores for the 12 participants adapted to expanded Chinese faces to change scores for the 12 participants adapted to compressed Chinese faces. As displayed in Figure 2c, although change scores for Chinese faces showed a similar pattern to that observed for Caucasian faces, the number of expanded Chinese faces selected as most normal did not increase any more for participants adapted to expanded Chinese faces (Mean change score = .08, *SE* = .53) than for participants adapted to compressed Chinese faces (Mean change score = -.33, *SE* = .33), $t(22) = .67$, $p > .20$, one-tailed.

The results of this study indicate that our child-friendly procedure is capable of eliciting opposing aftereffects in adult participants and thus is suitable for investigating the development of category-specific face prototypes. Despite there being only 10 test trials (five per race), adults' normality judgments shifted such that the number of expanded faces selected as most normal increased more for the race of face that was expanded than for the race of face that was compressed. However, when we examined the data separately for Caucasian and Chinese test faces, we discovered that although the pattern of results was similar for the two face races, the effect was being driven largely by simple aftereffects for Caucasian faces. Such a pattern of results contrasts with previous reports of similar aftereffect sizes for own- and other-race faces (Jaquet et al., 2008). The lack of simple aftereffects for Chinese faces in the present study may be because we used children's faces as both test and adapting stimuli whereas past research has relied on adult faces. Johnston, Kanazawa, Kato, and Oda (1997) have suggested that among adults, male and female children's faces may represent separate clusters in face space apart from adult faces and operate in a manner comparable to other-race faces. Furthermore, past research has demonstrated that adults exhibit an "other-age effect" such that children's faces are less accurately recognized than adult faces (Kuefner, Macchi Cassia, Picozzi, & Bricolo, 2008). Given that adults perceive both children and other-race individuals as members of an out-group, Chinese children's faces represent an extreme out-group and a face category with which Caucasian adults have very little experience (see General Discussion). Thus it is not surprising that adults demonstrated smaller aftereffects for Chinese children's faces than for Caucasian children's faces. Nonetheless, the results of our overall analysis provide evidence for race-contingent opposing aftereffects, and the trend toward simple aftereffects for both face races suggests that the Chinese adapting stimuli were at least sufficiently effective to counteract any generalization from the Caucasian adapting stimuli.

Because the identity of each of the test faces was different from the identities used during adaptation, the shift in normality judgments was specific to face category and not to individual face identity. The size and location of the adapting stimuli varied across storybook pages and thus these opposing aftereffects cannot be attributed to low-level adaptation. Furthermore, it is unlikely that adults' post-adaptation normality judgments can be attributed to the messages associated with top-up faces (e.g., "I agree!") rewarding the selection of distorted faces. Top-up faces were distorted in a way that was consistent with adaptation; adults saw one face from each race prior to each test trial, and the messages were independent of the participant's response.

A potential alternative explanation for the opposing aftereffects elicited in our study is the mere exposure effect. According to the mere exposure effect, repeated contact with an item leads to increased liking for that item or ones similar to it at a later time (Zajonc, 2001). However, this explanation is highly unlikely given that Rhodes, Halberstadt, Jeffery, and Palermo (2005) have demonstrated that the mere exposure effect is specific for individual face identities and does not generalize to composite faces made up of the faces previously shown. Such averaged composite faces are highly similar to the individual faces shown during initial exposure, yet attractiveness ratings for face composites of seen faces are no greater than attractiveness ratings for face composites of unseen faces. Furthermore, past studies have failed to find opposing aftereffects following adaptation to faces that belong to the same face category (e.g., the Super-Chinese and Chinese faces used in Jaquet et al., 2007). If repeated contact were sufficient to elicit opposing aftereffects, then exposure to compressed Chinese faces and expanded Super-Chinese faces (which are as perceptually distinct as compressed Chinese faces and expanded Caucasian faces) should have simultaneously increased preferences for compressed Chinese faces and expanded Super-Chinese faces. Because mere exposure cannot entirely account for opposing aftereffects, our results suggest that adaptation to oppositely distorted Chinese and Caucasian faces in the context of a storybook is sufficient to produce opposite shifts in the race-specific face prototypes. In Experiments 2 and 4a, we used a similar methodology to investigate whether 8- and 5-year-old children possess adult-like race-specific face prototypes.

Experiment 2: Race-Contingent Opposing Aftereffects in 8-Year-Olds

Because our method in Experiment 1 was successful in eliciting race-contingent opposing aftereffects in adults, we used a similar design to investigate whether 8-year-old children demonstrate evidence for adult-like dissociable face prototypes that code for race. However, in order to provide the most sensitive measure of opposing aftereffects, we modified our task in several ways that made it more consistent with the method found to successfully elicit simple attractiveness aftereffects in 8-year-olds (Anzures et al., 2009). First, children were asked to rate the attractiveness of a series of individual faces rather than to select the most normal-looking face in a face pair. (During pilot testing (n = 14) we tested children with the adult method but presented them with ± 20% faces. Individual children tended to either always pick the expanded face in each pair or always pick the compressed face in each pair pre-adaptation.) Anzures et al. demonstrated that simple attractiveness aftereffects can be successfully measured in 8-year-olds by using a 5-point attractiveness rating scale and thus we adopted this method for the present study. Second, as in the study by Anzures et al., we used larger distortions for both the test (±70%) and adapting stimuli (±90%). Children require greater differences among faces in order to consistently rate unaltered faces as more attractive than faces with compressed or expanded features pre-adaptation (Anzures et al.) and are generally less sensitive to facial distortions that make a face grotesque/distinctive (such as by Thatcherization) (Gilchrist & McKone, 2003; McKone & Boyer, 2006; Mondloch et al., 2004).

Similar to Experiment 1, children were read a 5-minute storybook in which Caucasian faces were distorted in one direction (e.g., expanded) while Chinese faces were distorted in the opposite direction (i.e., compressed). Both before and after adaptation, children were shown an undistorted, expanded (+70%), and compressed (-70%) face of each race and asked to rate its attractiveness on a 5-point scale. Opposing aftereffects would be evident if ratings of +70% faces increased more for the race of face that was expanded during adaptation than for the race of face that was compressed. Likewise, ratings of -70% faces would increase more for the race of face that was compressed during adaptation than for the race of face that was expanded. If 8-year-olds demonstrate evidence for opposing aftereffects, this would suggest that like adults, they code race in reference to dissociable face prototypes.

Method

Participants. Twenty-four Caucasian 8-year-olds (±6 months; 12 females) participated in this experiment. In this and all subsequent experiments, parents provided written informed consent and each child provided verbal assent. Three additional children were tested but excluded from all analyses because they failed to pass pre-adaptation criterion trials (n = 2) or because they assigned the same rating for each face during all trials (n = 1).

Materials. Similar to the task used with adults, the experiment consisted of three phases. The face identities used as stimuli were the same for adults and 8-year-olds; however, the faces were distorted by a greater amount in all phases of the experiment because children are generally less sensitive than adults to some facial distortions (Anzures et al., 2009; Mondloch et al., 2004; but see Gilchrist & McKone, 2003). Furthermore, rather than choosing the most normal face in a face pair, children were shown individual faces and asked to rate the attractiveness of each face on a 5-point scale. Attractiveness ratings were used in order to parallel the procedure employed by Anzures et al. in their examination of simple attractiveness aftereffects in 8-year-olds. Pre- and post-adaptation stimuli consisted of 12 face identities that were divided into two sets of six face identities (three Caucasian faces per set). Within each set, there was an undistorted, expanded (+70%), and compressed (-70%) face for each race (see Figure 1b). Faces from one set were presented pre-adaptation and faces from the other set were presented post-adaptation; the order of the sets was counterbalanced across participants and within each set, faces appeared in one of two orders. Face race alternated across trials and gender was counterbalanced for each race across pre- and post-adaptation trials, such that if two Chinese male faces and one Chinese female face were presented pre-adaptation then one Chinese male face and two Chinese female faces were presented post-adaptation. Adaptation stimuli were presented in the context of a computerized storybook that was identical to that read to adults. However, in order to ensure that the level of distortion was greater for adaptation stimuli than for rating stimuli, adaptation stimuli were distorted by ±90%.

Procedure. The procedure was modeled after the task used by Anzures et al. (2009) in their investigation of simple aftereffects in 8-year-olds. Prior to testing, children completed two sets of criterion trials to ensure they understood the rating scale that would be used throughout the task. In the first set of criterion trials, they were simultaneously shown three presents that varied in attractiveness. They were then shown each present one at a time and asked to rate how pretty the present was using a 5-point cup rating scale in which the largest cup meant "very, very pretty" and the smallest cup meant "not at all pretty." In the second set of criterion trials, children were shown three balloons and asked to rate how pretty each balloon was using the same scale. Children were excluded from the final analysis if they made more than one "error," defined as rating a less attractive item (e.g., a paper bag) as more attractive than the next most attractive item (e.g., a green present with yellow polka dots).

Following completion of the criterion trials, children were told that they were going to see pictures of children attending a birthday party and that their job was to rate how pretty or handsome each child is. Each child viewed six faces (three Caucasian); all three levels of distortion (undistorted, +70%, -70%) were presented for each race. Faces remained on the screen until children pointed to the cup that represented their attractiveness rating. Once pre-adaptation rating trials were completed, they were read a 5-minute storybook about two birthday parties. Similar to Experiment 1, half of the children were adapted to expanded Caucasian faces (+90%) and compressed Chinese faces (-90%) and the other half were adapted to compressed Caucasian faces and expanded Chinese faces. The identities of the adaptation faces differed from those used during pre- and post-adaptation trials, and only one race of face was presented on each page. Following the storybook, children were shown an additional six faces and asked to rate the attractiveness of each face. Faces remained on the screen for 3 seconds and were then replaced with a blank screen until a response had been made. The top-up procedure was identical to that used in Experiment 1, except that top-up faces were distorted by ±90% rather than ±60%.

Results and Discussion

Mean attractiveness ratings were calculated for distorted faces (-70%, +70%) pre- and post-adaptation for the race that was expanded during adaptation and for the race that was compressed. To determine whether 8-year-old children showed opposing aftereffects, change scores were calculated for +70% and -70% faces for the expanded face race and the compressed face race by subtracting the pre-adaptation rating from the post-adaptation rating. For each adaptation condition half of the ratings were from Caucasian faces and half were from Chinese faces. Because change scores may be influenced by pre-adaptation ratings, we first examined whether pre-adaptation attractiveness ratings for the two levels of distortion differed for the race of face to be expanded versus the race of face to be compressed. A 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated measures ANOVA for pre-adaptation trials revealed a main effect of distortion, $F(1, 23) = 6.46, p < .05, \eta_p^2 = .22$, but no effect of adaptation condition and no adaptation condition x distortion interaction, *p*s > .30. Expanded faces were rated as more attractive ($M = 2.14$, $SE = .27$) than compressed faces ($M = 1.73$, $SE = .23$), but the size of this difference did not differ for the race of face to be expanded relative to the race of face to be compressed.

A 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated measures ANOVA with the change in attractiveness ratings as the dependent variable revealed a significant main effect of distortion, $F(1, 23) = 4.90, p < .05, \eta_p^2 = .18$; ratings of -70% faces increased more than ratings of +70% faces. There was no main effect of adaptation condition, $p > .50$; however, the ANOVA revealed a significant distortion by adaptation condition interaction, $F(1, 23) = 9.28$, $p < .01$, $\eta_p^2 = .29$. As shown in Figure 3a, ratings of +70% faces increased more for the race of face that was expanded during adaptation (Mean change score = 1.08, $SE = .24$) than for the race of face that was compressed (Mean change score = -.04, $SE = .31$), $t(23) = 2.54$, $p < .01$, one-tailed. In contrast, ratings of -70% faces increased more for the race of face that was compressed during adaptation (Mean change score = 1.58, $SE = .31$) than for the race of face that was expanded (Mean change score = .58, $SE = .21$), $t(23) = 2.42$, $p < .01$, one-tailed.

In order to determine whether the presence of opposing aftereffects was driven entirely by simple aftereffects for a single race (e.g., for Caucasian faces) or by the combination of simple aftereffects for both races, we examined the data using stimulus race as a factor. We first examined whether participants exhibited evidence for simple aftereffects for Caucasian faces. To do so, we compared change scores for the 12 children adapted to expanded Caucasian faces to change scores for the 12 children adapted to compressed Caucasian faces. An ANOVA with one repeated measure (distortion: +70%, -70%) and one between-subjects factor (adaptation condition: expanded Caucasian, compressed Caucasian) revealed no main effects (*ps* > .10) but a significant two-way interaction, $F(1, 22) = 6.31$, $p < .05$, $\eta_p^2 = .22$. As shown in Figure 3b, attractiveness ratings for +70% Caucasian faces increased more for children adapted to expanded Caucasian faces (Mean change score = 1.42, $SE = .38$) than for children adapted to compressed Caucasian faces (Mean change score = .17, $SE = .46$), $t(22) = 2.10$, $p < .05$, one-tailed. Likewise, attractiveness ratings for -70% Caucasian faces increased more for

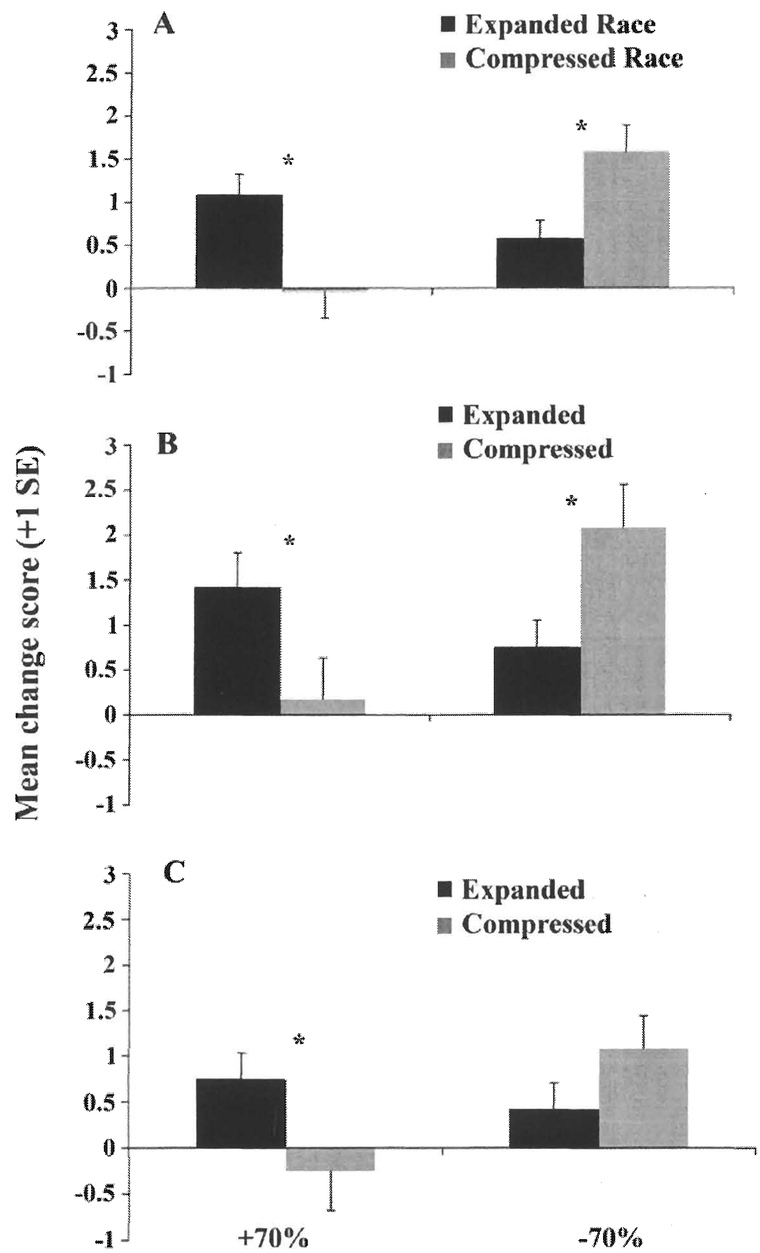

Figure 3. A. Among 8-year-olds, mean change scores for +70% and -70% test faces for the race of face that was expanded versus the race of face that was compressed during adaptation. B. For Caucasian faces, mean change scores for +70% and -70% test faces for 8-year-olds adapted to expanded versus compressed Caucasian faces. C. For Chinese faces, mean change scores for +70% and -70% test faces for 8-year-olds adapted to expanded versus compressed Chinese faces.

children adapted to compressed Caucasian faces (Mean change score = 2.08, *SE* = .48) than for children adapted to expanded Caucasian faces (Mean change score = .75, *SE* = .30), $t(22) = 2.33$, $p < .05$, one-tailed.

To determine whether 8-year-olds exhibited evidence for simple aftereffects for Chinese faces, we compared change scores for the 12 children adapted to expanded Chinese faces to change scores for the 12 children adapted to compressed Chinese faces. We then conducted an ANOVA with one repeated measure (distortion: +70%, -70%) and one between-subjects factor (adaptation condition: expanded Chinese, compressed Chinese). There were no main effects (*ps* > .10) but there was a significant interaction, $F(1, 22) = 5.79$, $p < .05$, $\eta_p^2 = .21$. As shown in Figure 3c, attractiveness ratings for +70% Chinese faces increased more for children adapted to expanded Chinese faces (Mean change score = .75, *SE* = .28) than for children adapted to compressed Chinese faces (Mean change score = -.25, *SE* = .43), $t(22) = 1.96$, $p < .05$, one-tailed. Similarly, attractiveness ratings for -70% Chinese faces increased more for children adapted to compressed Chinese faces (Mean change score = 1.08, *SE* = .36) than for children adapted to expanded Chinese faces (Mean change score = .42, *SE* = .29), although this trend was only marginally significant, $t(22) = 1.45$, $p = .08$, one-tailed.

The results of this study indicate that 8-year-old children demonstrate evidence for race-contingent opposing aftereffects. Attractiveness ratings for +70% test faces increased more for the race of face that was expanded during adaptation than for the race of face that was compressed. Concurrently, attractiveness ratings for -70% test faces increased more for the race of face that was compressed during adaptation than for the race of face that was expanded. There is no evidence to suggest that this effect was driven entirely by simple aftereffects for own-race faces; children demonstrated evidence for simple attractiveness aftereffects for both Caucasian and Chinese faces. It is interesting that 8-year-olds exhibited evidence for simple aftereffects for both races while adults demonstrated significant simple aftereffects only for Caucasian faces, despite showing significant opposing aftereffects. However, because we used different test trials and different distortions when testing adults and 8-year-olds, any differences in the magnitude of aftereffects must be interpreted with caution. Although this pattern of results is consistent with the hypothesis that 8-year-olds' face space is more malleable than adults (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2006), the larger aftereffects may be the result of using more distorted adapting stimuli in the 8-year-old version of the task (±90%) than in the adult version of the task (±60%). Moreover, because we used children's faces as test and adapting stimuli, 8-year-olds viewed a category of faces with which they have a great deal of experience, while adults viewed children's faces with which they have little experience (see General Discussion). Nonetheless, our results suggest that by 8 years of age children process own- versus other-race faces relative to race-specific prototypes.

Experiment 3: Simple Attractiveness Aftereffects in 5-Year-Olds

The results of Experiment 2 suggest that 8-year-olds' face space is organized in a manner comparable to adults' with regard to race. Similar to adults, 8-year-olds rely on norm-based coding (Anzures et al., 2009) and possess multiple face prototypes that code for race of face. There were two goals in Experiment 3. First, we sought to determine whether children younger than 8 years of age process faces using norm-based coding and whether their prototype is continuously updated as a result of face experience. To date, no published study has investigated whether children younger than 8 years of age demonstrate evidence for simple attractiveness aftereffects (but see Vida & Mondloch, 2009 for evidence of expression aftereffects in 5-year-old children). Using a design similar to Anzures et al., we investigated whether 5-year-old children demonstrate evidence for simple attractiveness aftereffects. Second, in order to investigate whether 5-year-old children possess category-specific face prototypes (Experiment 4), it was necessary to first design and validate a sensitive measure for eliciting face aftereffects in 5-year-old children.

In a pilot study we asked 5-year-olds to rate both undistorted and distorted faces on a 3-point cup-rating scale. Although Cooper et al. (2006) demonstrated that 4-year-olds are capable of using a 3-point rating scale for facial attractiveness, pilot testing (n = 17) revealed that pre-adaptation children frequently used a rating of 1, thus eliminating the possibility of attractiveness ratings decreasing post-adaptation, or a rating of 3, thus eliminating the possibility of attractiveness ratings increasing post-adaptation. Thus, rather than asking children to rate the attractiveness of a series of individual faces, we simultaneously presented children with two versions of the same identity and asked them to point to the prettiest or most handsome face in each pair. Each face pair consisted of an undistorted Caucasian face paired with either an expanded (+70%) or compressed (-70%) face of the same identity. We expected children to almost exclusively select the undistorted member of each pair pre-adaptation. Simple aftereffects would be evident if the number of +70% faces selected increased more for children adapted to expanded faces than for children adapted to compressed faces and if the number of -70% faces selected increased more for children adapted to compressed faces than for children adapted to expanded faces.

Method

Participants. Forty-eight Caucasian 5-year-olds (±6 months; 27 female) participated in this experiment. One additional child was tested but excluded from all data analyses because she consistently selected both facial distortions as more attractive than unaltered faces pre-adaptation. In this experiment, no children were excluded on the basis of failing to meet criterion.

Materials. Stimuli consisted of colored photographs of Caucasian 4-to 6-year-old children. All faces were distorted using the spherize function in Adobe Photoshop. The experiment consisted of three phases: pre-adaptation attractiveness judgment trials, adaptation, and post-adaptation attractiveness judgment trials. Based on pilot testing, 5-year-olds were unable to use the 5-point cup rating scale, and therefore we used face pairs that consisted of an undistorted face paired with either an expanded (+70%) or compressed (-70%) face of the same identity. Pre- and post-adaptation stimuli were divided into two sets of 10 face pairs; each face pair was comprised of two versions of the same identity. In each set, there were five face pairs that were comprised of an unaltered face paired with a compressed face (-70%) and five face pairs that were comprised of an unaltered face paired with an expanded face (+70%) (see Figure 1c). For each pairing type (e.g., unaltered paired with expanded), two female pairings were assigned to one face set (e.g., pre-adaptation) and three were assigned to the other face set (i.e., post-adaptation). Face pairs from one set were shown pre-adaptation and face pairs from the other set were shown post-adaptation; the order in which the two sets were presented was counterbalanced across participants, and within each set faces appeared in one of two different orders. Adaptation stimuli were presented in the context of the computerized storybook used by Anzures et al. (2009). In this storybook, there was a single surprise birthday party that was attended by only Caucasian children (see Figure 1e). There were two versions of the storybook; one storybook contained faces with expanded features (+90%) and the other storybook contained faces with compressed features (-90%). The same eight identities were used in each storybook, and the identities of the adaptation faces differed from those used during pre- and post-adaptation trials.

Procedure. Upon arrival to the lab, children were seated in front of a computer screen and asked to complete two sets of criterion trials. In the first set of trials, children were simultaneously shown three presents that varied in attractiveness. They were then shown only two of the three presents at a time (n = 2 trials) and asked to point to the prettiest present in each pair. In the second set of criterion trials, children were simultaneously shown three balloons that varied in attractiveness and were again asked to select the prettiest balloon in each pair (n = 2 trials). Participants were excluded from all analyses if they made more than one "error", defined as selecting a less attractive item (e.g., a paper bag) as more attractive than the more attractive item with which it was paired (e.g., a green present with polka dots).

Following the criterion trials, children were told that they would see pairs of brothers and sisters and that their job was to tell the experimenter which brother/sister in each pair looked more handsome/pretty. Each child viewed 10 face pairs; there were five face pairs in which an undistorted face was paired with a compressed version of the same identity and there were five face pairs in which an undistorted face was paired with an expanded version of the same identity. The face pairs remained on the screen for 3 seconds and were then replaced by a blank screen. Participants indicated their choice by pointing to the side of the screen on which the prettier face appeared. The next trial did not begin until a response had been made.

Once the pre-adaptation trials were completed, participants were read a 5-minute story about a surprise birthday party (see Anzures et al., 2009 for details). Each page of the storybook contained between one and seven faces. Half of the participants were read a storybook in which all of the characters had compressed faces and the other half were read a storybook in which all of the characters had expanded faces. Following the storybook, participants were shown an additional 10 face pairs and asked to select the prettiest or most handsome face in each pair. Similar to pre-adaptation trials, stimuli remained on the screen for 3 seconds; however, in order to maintain adaptation, a single top-up face was presented following each trial. Top-up faces were paired with a comment designed to encourage participants, and each top-up face was distorted in a way that was consistent with adaptation.

Results and Discussion

For both pre- and post-adaptation trials, we recorded the number of times each participant selected a distorted face as more attractive than the unaltered face with which it was paired; separate tallies were kept for expanded versus compressed trials. Before calculating change scores, we first examined whether the number of distorted faces selected as most attractive for the two levels of distortion differed pre-adaptation between participants who were to be adapted to expanded faces versus participants who were to be adapted to compressed faces. An ANOVA with one repeated measure (distortion: +70%,

-70%) and one between-subjects factor (adaptation condition: expanded, compressed) revealed no main effects and no significant interaction, all *p*s > .10, indicating that children to be adapted to expanded faces were no more likely than children to be adapted to compressed faces to select either type of distortion as more attractive than undistorted faces. In all conditions, children selected fewer than 1.40 distorted faces (out of 5 trials) as most attractive when paired with an undistorted face; as such, there was sufficient room for children to show an increase in the number of distorted faces selected following adaptation.

Change scores for the +70% and -70% faces were calculated by subtracting the number of distorted faces selected pre-adaptation from the number of distorted faces selected post-adaptation for children adapted to expanded faces and for children adapted to compressed faces. An ANOVA with one repeated measure (distortion: +70%, -70%) and one between-subjects factor (adaptation condition: expanded, compressed) revealed a main effect of adaptation condition, $F(1, 46) = 5.49, p < .05, \eta_p^2 = .11$, such that children adapted to compressed faces demonstrated a greater increase in the overall number of distorted faces selected than children adapted to expanded faces. There was also a significant distortion by adaptation condition interaction, $F(1, 46) = 24.00, p < .001, \eta_p^2 = .34$. As shown in Figure 4, the number of -70% faces selected as most attractive increased more for children adapted to compressed faces (Mean change score = 1.71, $SE = .35$) than for children adapted to expanded faces (Mean change score = -.38, $SE = .23$), $t(46) = 4.93, p < .001$, one-tailed. Likewise, the number of +70% faces selected as most attractive increased more for children adapted to expanded faces (Mean change score = 1.17, $SE = .27$) than for children adapted to compressed faces (Mean change score = .50,

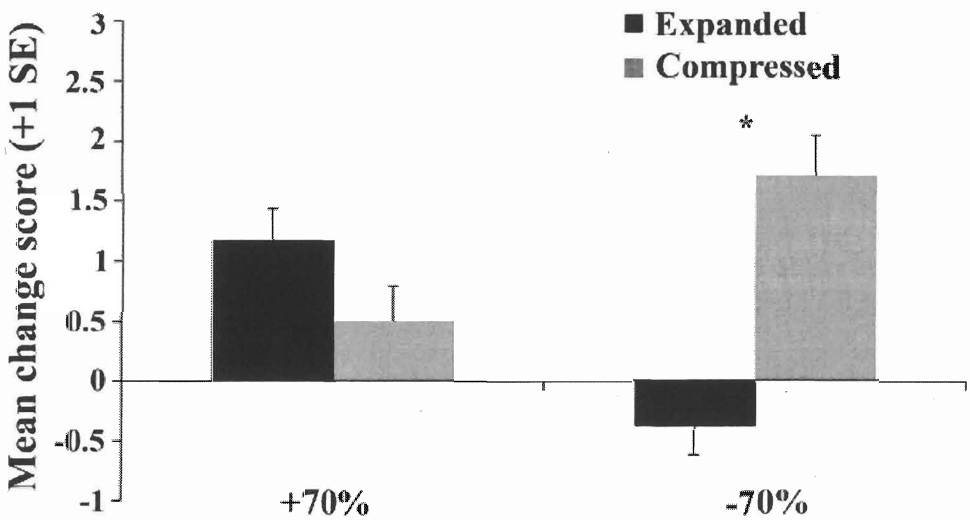

Figure 4. Mean change scores for +70% and -70% test faces for 5-year-olds adapted to expanded Caucasian faces and 5-year-olds adapted to compressed Caucasian faces.

$SE = .30$), although this difference was only marginally significant, $t(46) = 1.66, p = .05$, one-tailed. In a secondary analysis, we separately examined change scores for +70% and -70% faces for the 24 children adapted to compressed faces and for the 24 children adapted to expanded faces. Paired samples *t*-tests revealed that among children adapted to compressed faces, there was a greater increase in the number of compressed faces selected than in the number of expanded faces selected, $t(23) = 2.61, p < .01$, one-tailed. Similarly, among children adapted to expanded faces, there was a greater increase in the number of expanded faces selected than in the number of compressed faces selected, $t(23) = 4.84, p < .001$, one-tailed.

These results provide the first evidence of simple attractiveness aftereffects in 5-year-old children. Following adaptation, the number of -70% faces selected as most attractive increased more for children adapted to compressed faces than for children adapted to expanded faces. Likewise, the number of +70% faces selected as most attractive increased more for children adapted to expanded faces than for children adapted to compressed faces, although this increase was only marginally significant. Such a pattern of results provides evidence that 5-year-old children process faces using norm-based coding and that their prototype is continuously updated as a result of face experience. It is particularly impressive that during post-adaptation trials children selected a ±70% face, unlike any face they have previously encountered, as more attractive than an undistorted face. Such results emphasize the malleability of the face prototype and demonstrate that the prototype is capable of shifting even to somewhat unrealistic standards. Second, we were successful in our goal of creating a method sensitive to adaptation aftereffects in children as young as 5 years of age and thus it was possible to use this method in our subsequent examination of opposing aftereffects in 5-year-olds.

Experiment 4a: Race-Contingent Opposing Aftereffects in 5-Year-Olds

In Experiment 4a, we further explored the refinement of children's face space by determining whether opposing aftereffects could be elicited in 5-year-olds. Experiment 2 demonstrated that children as young as 8 possess dissociable face prototypes that code for race of face, but it is unknown whether children of a younger age process face race in a similar manner. Based on previous work, we hypothesized that young children have multiple prototypes for race of face. By 3 months, infants demonstrate a preference for own- versus other-race faces (Kelly et al., 2005), and by 6- to 9-months they discriminate own-race faces better than other-race faces (Kelly et al., 2007; Sangrigoli & de Schonen, 2004b). Like adults, children as young as 3 years show a recognition advantage for own-race faces over other-race faces (Chance et al., 1982; Sangrigoli & de Schonen, 2004a). While the aforementioned studies suggest that young children's face space is most useful for discriminating own-race faces, it is unknown whether 5-year-olds possess race-specific face prototypes or rely on a single prototype to encode faces of all races.

In Experiment 4a, we adapted 5-year-old children to Caucasian and Chinese faces distorted in opposite directions using the adaptation procedure (i.e., storybook) found to successfully elicit opposing aftereffects in 8-year-olds; however, we modified the test trials in this task to be consistent with those used in our examination of simple aftereffects in 5-year-olds. Children were shown Caucasian and Chinese face pairs and asked to select the prettiest or most handsome face in each pair. Similar to Experiment 3, each face pair consisted of an undistorted face paired with an expanded (+70%) or compressed (-70%) face of the same identity. Opposing aftereffects would be evident if the number of +70% faces selected as most attractive increased more for the race of face that was expanded during adaptation than for the race of face that was compressed. Simultaneously, the number of -70% faces selected as most attractive would increase more for the race of face that was compressed during adaptation than for the race of face that was expanded. If such opposing aftereffects were generated, this would indicate that children as young as 5 years of age possess multiple prototypes for race of face.

Method

Participants. Twenty-four Caucasian 5-year-olds (±6 months; 14 female) participated. Two additional children were tested but excluded from all data analyses because they were unable to follow task instructions; both children began selecting only the faces on the right side of the screen during the middle of the task and refused to look at the faces on the left side. No children were excluded on the basis of failing to meet criterion.

Materials. Stimuli consisted of the colored photographs of Caucasian and Chinese 4- to 6-year-old children used in Experiments 1 and 2. All faces were distorted using the spherize function in Adobe Photoshop. The experiment consisted of three phases: pre-adaptation attractiveness judgment trials, adaptation, and post-adaptation attractiveness judgment trials. Pre- and post-adaptation stimuli were divided into two sets of 16 face pairs (eight per race); each face pair was comprised of two versions of the same identity. In each set, there were four face pairs for each race that consisted of an unaltered face paired with a compressed face (-70%) and four face pairs for each race that consisted of an unaltered face paired with an expanded face (+70%) (see Figure 1c). Face pairs from one set were shown pre-adaptation and face pairs from the other set were shown post-adaptation; the order in which the two sets were presented was counterbalanced across participants, and within each set faces appeared in one of two different orders. Adaptation stimuli were presented in the context of the computerized storybook used in Experiment 2.

Procedure. Prior to testing, children completed four criterion trials identical to those described in Experiment 3. Likewise, attractiveness judgment trials were similar to those described in Experiment 3 except that participants completed 16 pre-adaptation trials (eight Caucasian) and 16 post-adaptation trials (eight Caucasian). Adaptation top-up was identical to that used in Experiment 2. Following pre-adaptation trials, children were read one of two versions of a storybook. The storybook was about two separate birthday parties, one that was attended only by Caucasian children and the other that was attended only by Chinese children. Half of the participants were adapted to expanded Caucasian faces (+90%) and compressed Chinese faces (-90%) and the other half were adapted to compressed Caucasian faces and expanded Chinese faces.

Results and Discussion

For each participant, we recorded the number of distorted faces selected on expanded and compressed trials for the race of face that was compressed during adaptation (Caucasian for half of the participants; Chinese for the other half) and for the race of face that was expanded during adaptation. Prior to calculating change scores, we examined whether the number of +70% and -70% faces selected as most attractive pre-adaptation differed for the race of face to be expanded and the race of face to be compressed. A 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%,

-70%) repeated measures ANOVA for pre-adaptation trials revealed no main effects, *ps* > .30, but a significant adaptation condition by distortion interaction, $F(1, 23) = 5.07, p < .05, \eta_p^2 = .18$. During pre-adaptation trials, a greater number of +70% faces were chosen for the race of face to be compressed ($M = 1.00$, $SE = .23$) than for the race of face to be expanded ($M = .58$, $SE = .13$), $t(23) = 2.01, p < .05$, two-tailed. However, the number of -70% faces selected during pre-adaptation did not differ between the race of face to be compressed ($M = .63$, $SE = .22$) and the race of face to be expanded ($M = .75$, $SE = .18$), $t(23) = .68, p > .50$, two-tailed. However, given that in all conditions, children on average selected the distorted face as being more attractive in no more than one of four face pairs, this interaction does not suggest that children initially viewed distorted faces as being more attractive than their undistorted counterparts, and in all cases there was no ceiling effect.

To determine whether 5-year-olds demonstrated evidence for race-contingent opposing aftereffects, we first calculated change scores for both the expanded face race and the compressed face race by subtracting the number of distorted faces selected pre-adaptation from the number of distorted faces selected post-adaptation for each level of distortion. We then conducted a 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated measures ANOVA with the change in the number of distorted faces chosen as the dependent variable. There were no main effects, *ps* > .20, but there was a significant interaction, $F(1, 23) = 9.38, p < .01, \eta_p^2 = .29$. As shown in Figure 5a, the number of +70% faces selected as most attractive increased more for the race of face that was expanded during adaptation (Mean change score = .46, $SE = .23$)

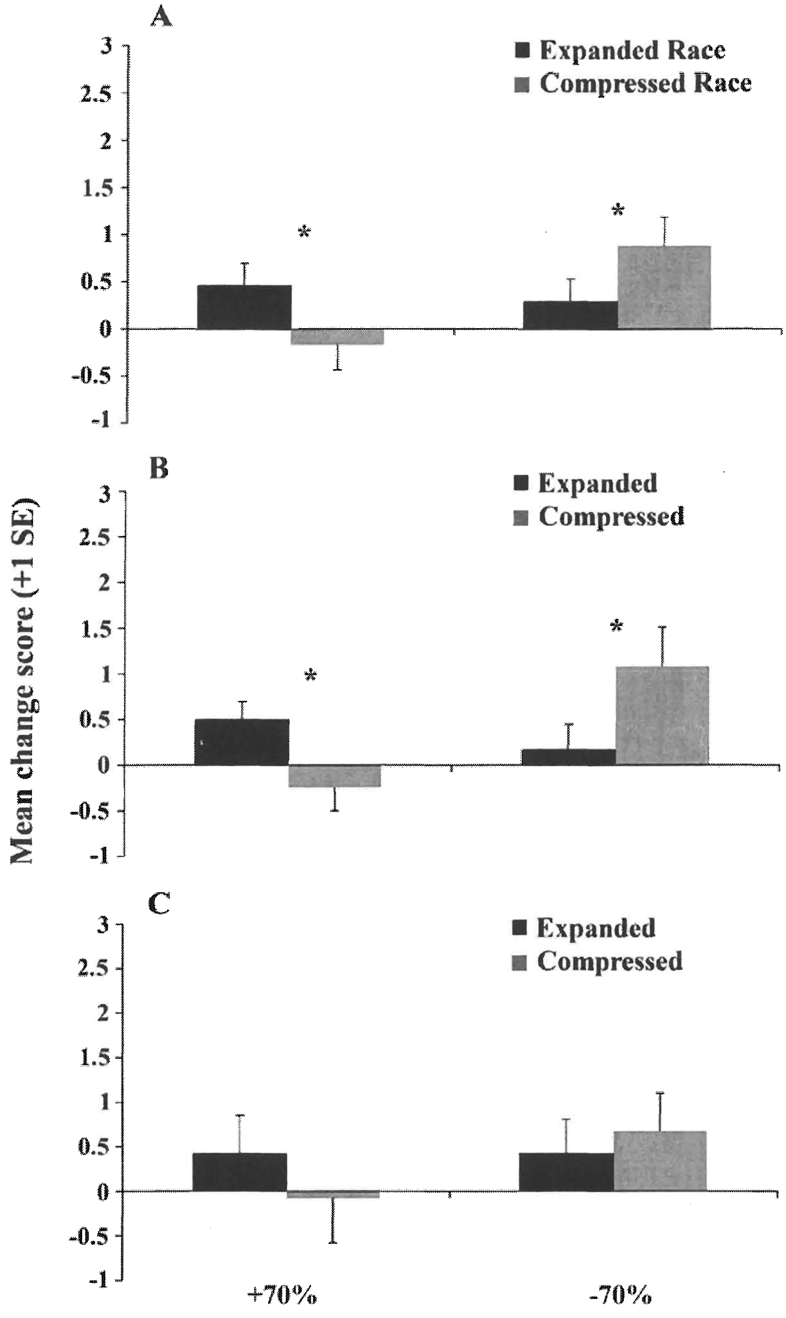

Figure 5. A. Among 5-year-olds, mean change scores for +70% and -70% test faces for the race of face that was expanded versus the race of face that was compressed during adaptation. B. For Caucasian faces, mean change scores for +70% and -70% test faces for 5-year-olds adapted to expanded versus compressed Caucasian faces. C. For Chinese faces, mean change scores for +70% and -70% test faces for 5-year-olds adapted to expanded versus compressed Chinese faces.

than for the race of face that was compressed (Mean change score = -.17, *SE* = .27), $t(23) = 2.01$, $p < .05$, one-tailed. In contrast, the number of -70% faces selected as most attractive increased more for the race of face that was compressed during adaptation (Mean change score = .88, *SE* = .30) than for the race of face that was expanded (Mean change score = .29, *SE* = .23), $t(23) = 1.77$, $p < .05$, one-tailed.

Although our results suggest the existence of opposing aftereffects, it may have been the case that the effect was driven primarily by adaptation to a single race rather than by simultaneous simple aftereffects for both races. In order to determine whether this was the case, we examined the data using stimulus race as a factor. Similar to our analysis of race-specific simple aftereffects for 8-year-olds, we compared change scores for the 12 children adapted to expanded Caucasian faces to change scores for the 12 children adapted to compressed Caucasian faces. An ANOVA with one repeated measure (distortion: +70%, -70%) and one between-subjects factor (adaptation condition: expanded Caucasian, compressed Caucasian) revealed no main effects, all *p*s > .10, but a significant interaction, $F(1, 22) = 6.63$, $p < .05$, $\eta_p^2 = .23$. As shown in Figure 5b, the number of +70% Caucasian faces selected as most attractive increased more for children adapted to expanded Caucasian faces (Mean change score = .50, *SE* = .19) than for children adapted to compressed Caucasian faces (Mean change score = -.25, *SE* = .25), $t(22) = 2.37$, $p < .05$, one-tailed. Likewise, the number of -70% Caucasian faces selected as most attractive increased more for children adapted to compressed Caucasian faces (Mean change score = 1.08, *SE* = .43) than for children adapted to expanded Caucasian faces (Mean change score = .17, *SE* = .27), $t(22) = 1.79$, $p < .05$, one-tailed. Overall, this pattern parallels the results of Experiment 3 and suggests the existence of simple attractiveness aftereffects for Caucasian faces, similar to adults and 8-year-olds.

In order to determine whether, like 8-year-olds, 5-year-olds demonstrated evidence for simple aftereffects for Chinese faces, we first compared change scores for the 12 children adapted to expanded Chinese faces to change scores for the 12 children adapted to compressed Chinese faces. An ANOVA with one repeated measure (distortion: +70%, -70%) and one between-subjects factor (adaptation condition: expanded Chinese, compressed Chinese) revealed no main effects, all *ps* > .40. Unlike our analysis of Caucasian faces, there was no significant two-way interaction, $F(1, 22) = .69$, $p > .40$, $\eta_p^2 = .03$. As shown in Figure 5c, changes in the number of +70% and -70% faces selected as most attractive did not systematically differ as a function of adaptation condition (*ps* > .40).

The results of this experiment indicate that while 5-year-olds appear to exhibit race-contingent opposing aftereffects, unlike 8-year-olds, the effect is driven largely by simple aftereffects for Caucasian faces, a pattern similar to that seen in adults. Among 5-year-olds, there was no shift in the number of distorted faces selected as most attractive for Chinese faces following adaptation. Whereas the lack of simple aftereffects for Chinese faces in adults can be accounted for by adults' limited experience with children's faces (especially Chinese children's faces), such an explanation does not hold for 5-year-olds. Young children are exposed to a greater number of different children's faces than are adults, and thus the absence of simple aftereffects for Chinese children's faces is likely attributable to 5-year-olds' lack of experience with other-race faces.

There are several potential explanations for the lack of simple aftereffects for Chinese faces among 5-year-olds. It may have been the case that any shift in the Chinese prototype following adaptation was counteracted by generalization from the Caucasian to the Chinese faces. This is consistent with previous studies showing that adaptation to distorted faces of one sex (e.g., male) produces simple attractiveness aftereffects for faces of both sexes when there is no exposure to the second face category (i.e., female) during adaptation, indicating that there are both shared and selective mechanisms responsible for coding male and female faces (Jaquet & Rhodes, 2008). In young children, the mechanisms responsible for coding Caucasian faces may be given greater weight than those used for Chinese faces, and adaptation to the distortion used for Caucasian faces would therefore generalize to Chinese faces. Another possibility is that because of 5-year-old children's limited experience with faces of other races, they have not yet formed a prototype for Chinese faces and were unable to do so during the adaptation phase. Thus when presented with a series of Chinese faces they have no category-specific face space to reference and there is no Chinese face prototype to shift. Overall, these results suggest that 5-year-olds' face space is less refined than that of 8-year-olds, which may be because of 5-year-olds' limited experience with other-race faces. In the final experiment, we examined whether 5-year-olds exhibit evidence for opposing aftereffects for male and female children's faces, which represent highly meaningful face categories with which young children presumably have comparable levels of experience.

Experiment 4b: Sex-Contingent Opposing Aftereffects in 5-Year-Olds

Although the results of Experiment 4a suggest that young children may be using the same prototype and coding dimensions to discriminate multiple face categories, it may be the case that 5-year-olds simply do not perceive race as a meaningful face category. A different pattern of results might emerge if 5-year-olds were adapted to distorted faces from two face categories that carry greater meaning in their current environment, such as male versus female. Two lines of evidence suggest that young children may reference separable prototypes for male and female faces. First, gender is a highly salient category for young children. From an early age, children form exceptionally rigid gender schemas (Martin & Halverson, 1981), and by age 3, they demonstrate a preference for interacting with same-sex peers (Maccoby, 2002). Second, the ability to discriminate between the two sexes has marked evolutionary significance. Cosmides et al. (2003) have suggested that it is evolutionarily adaptive to automatically encode dimensions that provide information about the life-history stage of a given individual, such as sex and age. These dimensions provide an indication of the reproductive capabilities of an individual and thus allow for probabilistic inferences about mating potential. From an evolutionary perspective, it seems unlikely that race would be encoded as automatically and effortlessly as sex and age. Early hominid societies were separated by great geographical distance and it is highly unlikely that individuals of different races would have encountered one another (Cosmides et al., 2003; Kurzban, Tooby, & Cosmides, 2001). Given such infrequent contact, it does not seem plausible that natural selection would have favored preferential and automatic encoding of race. Therefore, whereas dimensions such as sex and age may be automatically encoded from an early age, the discrimination of race may be more socially mediated and dependent upon considerable experience with other-race faces.

In order to determine whether young children reference multiple prototypes for face categories that carry meaning in their current environment, we examined whether 5-year-olds show opposing aftereffects for male and female faces. The design of our experiment was identical to that used in Experiment 4a, except that children were tested with male and female Caucasian faces rather than with Chinese and Caucasian faces. If children demonstrate evidence for sex-contingent opposing aftereffects with shifts in attractiveness judgments for both male and female faces, this would suggest that like adults, they possess category-specific prototypes but only for highly salient face categories with which they have a great deal of experience and that carry meaning in their environment.

Method

Participants. Twenty-four Caucasian 5-year-olds (±6 months; 12 female) participated in this experiment. One additional child was tested but excluded from all data analyses because he pointed to both faces in each pre-adaptation trial, stating that they were equally attractive. No children were excluded on the basis of failing to pass criterion trials.

Materials. Stimuli consisted of the colored photographs of Caucasian 4- to 6-year-old children used in Experiment 3. All faces were distorted using the spherize function in Adobe Photoshop. The experiment consisted of three phases: pre-adaptation attractiveness judgment trials, adaptation, and post-adaptation attractiveness judgment trials. Pre- and post-adaptation stimuli were divided into two sets of 16 face pairs (eight per sex); each face pair was comprised of two versions of the same identity. In each set, there were four face pairs for each sex that consisted of an unaltered face paired with a compressed face (-70%) and four face pairs for each sex that consisted of an unaltered face paired with an expanded face (+70%) (see Figure 1c). Face pairs from one set were shown pre-adaptation and face pairs from the other set were shown post-adaptation; the order in which the two sets were presented was counterbalanced across participants, and within each set faces appeared in one of two different orders. Faces of twelve different identities (six female, six male) were used as adaptation stimuli. These faces were presented in the context of the 5-minute computerized storybook used in Experiment 4a; however, the Caucasian identities used in Experiment 4a were replaced by Caucasian male faces and the Chinese identities were replaced by Caucasian female faces. Male and female faces were distorted in opposite directions (±90%), and only one sex of face was presented on each page and sex of face alternated from page to page.

Procedure. Prior to testing, children completed four criterion trials identical to those described in Experiments 3 and 4a. All other components of the procedure were identical to those described in Experiment 4a except that sex rather than race varied across test trials and adapting stimuli. Participants completed 16 pre-adaptation attractiveness judgment trials (eight female) and 16 post-adaptation attractiveness judgment trials (eight female). Following pre-adaptation trials, children were read one of two versions of a storybook. The storybook was about two separate birthday parties, one that was attended only by female children and the other that was attended only by male children. Half of the participants were adapted to expanded female faces (+90%) and compressed male faces (-90%) and the other half were adapted to compressed female faces and expanded male faces. After each post-adaptation trial two top-up faces were presented, one female and one male; similar to the previous experiments, top-up faces were distorted in a way that was consistent with adaptation. The first top-up face matched the sex of the previous trial and the second top-up face matched the sex of the upcoming trial.

Results and Discussion

For each participant, we recorded the number of distorted faces selected on expanded and compressed trials for the sex of face that was compressed during adaptation (female for half of the participants; male for the other half) and for the sex of face that was expanded during adaptation. Prior to calculating change scores, we examined whether the number of +70% and -70% faces selected as most attractive pre-adaptation differed for the sex of face to be expanded and the sex of face to be compressed. A 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated measures ANOVA for pre-adaptation trials revealed no main effects or interaction, *p*s > .30, indicating that children were no more likely to select the +70% or -70% face either for the sex of face to be expanded or for the sex of face to be compressed.

To determine whether 5-year-olds demonstrated evidence for sex-contingent opposing aftereffects, we first calculated change scores for both the expanded face sex and the compressed face sex by subtracting the number of distorted faces selected pre-adaptation from the number of distorted faces selected post-adaptation for each level of distortion. We then conducted a 2 (adaptation condition: expanded, compressed) x 2 (distortion: +70%, -70%) repeated measures ANOVA with the change in the number of distorted faces chosen as the dependent variable. There were no main effects, *p*s > .05, nor was there a significant interaction, $F(1, 23) = .48$, $p > .40$, $\eta_p^2 = .02$. As shown in

Figure 6a, the number of +70% faces selected as most attractive did not increase any more for the sex of face that was expanded during adaptation than for the sex of face that was compressed. Likewise, the number of -70% faces selected as most attractive did not increase any more for the sex of face that was compressed during adaptation than for the sex of face that was expanded.

Although these results do not provide any indication of sex-contingent opposing aftereffects in 5-year-olds, we examined the data separately for male and female faces in order to investigate whether children exhibited any evidence for simple aftereffects for either sex of face. We first examined whether participants exhibited evidence for simple aftereffects for female faces only. To do so, we compared change scores for the 12 children adapted to expanded female faces to change scores for the 12 children adapted to compressed female faces. An ANOVA with one repeated measure (distortion: +70%, -70%) and one between-subjects factor (adaptation condition: expanded female, compressed female) revealed no main effects and no significant interaction, *p*s > .20. As shown in Figure 6b, the number of +70% female faces selected as most attractive did not increase any more for children who were adapted to expanded female faces than for children who were adapted to compressed female faces. Likewise, the number of -70% female faces selected as most attractive did not increase any more for children who were adapted to compressed female faces than for children who were adapted to expanded female faces.

The comparable analysis for male faces revealed a main effect of distortion, $F(1, 22) = 4.60$, $p < .05$, $\eta_p^2 = .17$. Across adaptation condition, the number of expanded male faces selected as most attractive increased more than the number of compressed male

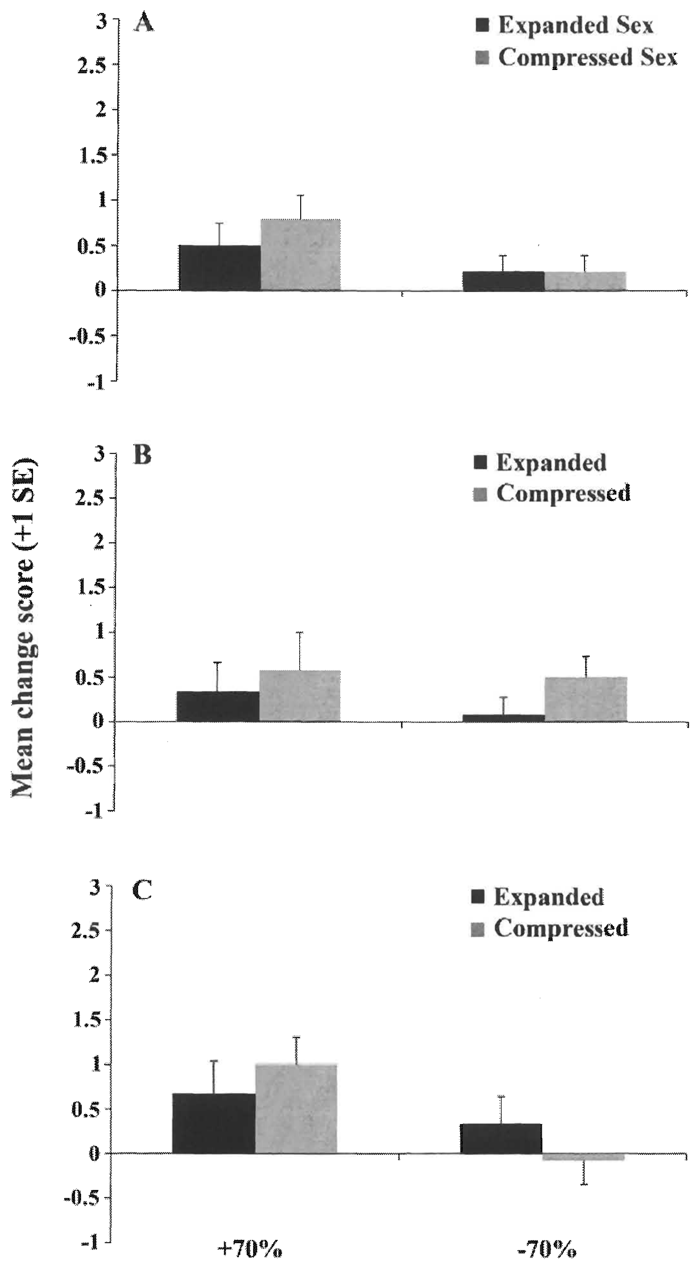

Figure 6. A. Among 5-year-olds, mean change scores for +70% and -70% test faces for the sex of face that was expanded versus the sex of face that was compressed during adaptation. B. For female faces, mean change scores for +70% and -70% test faces for 5-year-olds adapted to expanded versus compressed female faces. C. For male faces, mean change scores for +70% and -70% test faces for 5-year-olds adapted to expanded versus compressed male faces.

faces selected as most attractive. As shown in Figure 6c, neither the main effect of adaptation condition nor the interaction were significant, *p*s > .20. The number of +70% male faces selected as most attractive did not increase any more for children who were adapted to expanded male faces than for children who were adapted to compressed male faces. Likewise, the number of -70% male faces selected as most attractive did not increase any more for children who were adapted to compressed male faces than for children who were adapted to expanded male faces.

The results of this experiment suggest that 5-year-olds do not possess sex-specific face prototypes. Unlike adults (Jaquet & Rhodes, 2008; Little et al., 2005), children demonstrated no evidence for sex-contingent opposing aftereffects; furthermore, there was no evidence for simple attractiveness aftereffects for either sex of face. Because the aftereffects generated by simultaneous adaptation to male and female faces distorted in opposite directions essentially cancelled each other out, this would suggest that 5-year-olds rely on a single face prototype with regard to sex—at least for children's faces (see General Discussion). Collectively, the results of Experiments 4a and 4b indicate that 5-year-old children rely on a face space that is less refined than that of 8-year-olds and adults. Even for such a highly salient and meaningful social category as sex, 5-year-olds appear to reference a single prototype and its corresponding coding dimensions.

General Discussion

The goal of the present series of experiments was to investigate the organization and refinement of young children's face space. In order to examine the potential existence of category-specific face prototypes in children, it was first necessary to design and validate a child-friendly method for investigating opposing face aftereffects. After we established that our child-friendly storybook method was capable of eliciting opposing aftereffects in adult participants (albeit driven largely by shifts in adults' judgments of Caucasian faces) in Experiment 1, we investigated whether 5- and 8-year-old children demonstrated evidence for a similar reliance on category-specific face prototypes. The results of our study are the first to provide evidence for race-contingent opposing aftereffects in 8-year-olds (Experiment 2), suggesting that children as young as 8 years of age possess race-specific face prototypes. Furthermore, we are the first to demonstrate evidence for simple attractiveness aftereffects in children as young as 5 (Experiment 3), thereby indicating that similar to adults, 5-year-olds utilize norm-based coding and possess a face prototype that is continuously updated by experience. Lastly, using the method shown to elicit simple aftereffects in 5-year-olds, we found evidence for race-contingent opposing aftereffects in 5-year-old children; however, the effect was largely driven by simple aftereffects for Caucasian faces (Experiment 4a). Using a comparable method, we examined sex-contingent opposing aftereffects in 5-year-olds and found no evidence for shifts in attractiveness judgments for either male or female faces (Experiment 4b).

Race-Contingent Opposing Aftereffects in Adults and 8-Year-Old Children

In each of the experiments investigating race-contingent opposing aftereffects, follow-up analyses were conducted to determine whether participants exhibited evidence for simple aftereffects for the two face races. All three age groups showed simple aftereffects for Caucasian faces. However, 8-year-olds showed strong simple aftereffects for both face races, while adults demonstrated only a trend toward simple aftereffects for Chinese faces. There are three potential reasons for this discrepant pattern of results.

First, children's face space may be more malleable than that of adults. Sangrigoli et al. (2006) demonstrated that immersion in a novel face environment (e.g., a Korean child adopted into a French family) is capable of reversing the other-race effect in children as old as 9 years of age, whereas a similar degree of exposure does not alter adults' own-race recognition advantage (but see Nishimura et al., 2008 for evidence of comparable identity aftereffects in adults and 8-year-old children). Alternatively, larger simple aftereffects in 8-year-old children may be an artifact of our presenting children with larger distortions than adults both during adaptation (±90% versus ±60%) and during the judgment trials (±70% versus ±10%). Recent research has demonstrated that aftereffects are greater following adaptation to extremely distorted faces that are distant from the prototype than following adaptation to slightly distorted faces that remain close to the prototype (Jeffery et al., in press; Robbins, McKone, & Edwards, 2007). In the present study, we used larger distortions for children because Anzures et al. (2009) demonstrated that 8-year-olds require greater differences among faces in order to consistently rate unaltered faces as more attractive pre-adaptation than faces with compressed or expanded features. However, using larger distortions when testing children makes it difficult to interpret size differences in simple aftereffects between the two age groups because we cannot be certain that the magnitude of distortion was perceptually equivalent across adults and 8-year-olds. Because the difference between the Caucasian and the Chinese faces may have been exaggerated to a greater degree for 8-year-olds than it was for adults, the adapting stimuli may have served to shift the two prototypes to a greater extent for 8-year-old children.

The discrepant pattern of results between adults and 8-year-olds for Chinese faces may also have been because we used children's faces as both test and adapting stimuli. The previous study showing equivalent aftereffects for own- and other-race faces (Jaquet et al., 2008) used adult faces as both test and adapting stimuli. Adults have less experience than 8-year-olds with differentiating children's faces, and it may be the case that experience increases the strength of attractiveness aftereffects just as it increases the strength of identity aftereffects (Jiang, Blanz, & O'Toole, 2007). Although adults demonstrate comparable sex aftereffects for adult and child faces (Barrett & O'Toole, 2009), they recognize individual adult faces more accurately than individual child faces (Kuefner et al., 2008). This finding is consistent with Johnston et al.'s (1997) hypothesis that child faces are clustered separately from adult faces in adults' face space. In contrast to 8-year-olds who likely encounter Chinese children's faces in a variety of social contexts, adults are unlikely to receive this same experience.

Despite differences in the strength of simple aftereffects for the two face races, both adults and 8-year-olds demonstrated evidence for race-contingent opposing aftereffects. This study is the first to provide evidence that 8-year-olds' face space with regard to race is organized in a manner similar to adults. Nonetheless, because it was necessary to use larger test and adapting distortions for 8-year-olds than adults, it may be the case that 8-year-olds' face space is organized in a manner analogous to adults but lacks the refinement and sensitivity of a fully adult-like face space. This interpretation is consistent with Nishimura, Maurer, and Gao's (2009) recent finding that 8-year-old children tend to rely on the same coding dimensions as adults but exhibit difficulty utilizing more than one coding dimension at a time and with several studies showing that

8-year-olds often make more errors than adults on face perception tasks (Bruce et al., 2000; Freire & Lee, 2001; Mondloch et al., 2002), despite processing faces holistically (Carey & Diamond, 1994; de Heering et al., 2007; Mondloch et al., 2007; Pellicano & Rhodes, 2003; Tanaka et al., 1998), having a system that is tuned to human faces (Mondloch, Maurer, & Ahola, 2006) and being sensitive to numerous cues to facial identity (Freire & Lee, 2001; McKone & Boyer, 2006; Mondloch et al., 2002).

Simple and Opposing Aftereffects in 5-Year-Old Children

Similar to adults (Rhodes et al., 2003; Webster & MacLin, 1999) and 8-year-olds (Anzures et al., 2009), 5-year-old children exhibited evidence for simple attractiveness aftereffects. Such results suggest that 5-year-olds process faces using norm-based coding and possess a dynamic face prototype that is continuously updated by experience. These results are consistent with past research that has indicated that even 3-month-old infants are capable of forming a face prototype that represents the average of a set of faces shown during a single lab session (de Haan et al., 2001). However, 5-year-olds' face prototype may not be fully adult-like. Similar to 8-year-old children (see Anzures et al.), it was necessary to use larger distortions for 5-year-olds than for adults for both test (±70% versus ±10%) and adapting face stimuli (±90% versus ±60%). Furthermore, the ease with which we were able to shift 5-year-olds' prototype to extreme levels of distortion (i.e., they often selected ±70% faces as more attractive than undistorted faces) suggests that their prototype is extremely malleable and less refined than that of adults. Numerous studies have demonstrated that young children's face processing is adult-like in some ways (e.g., Carey & Diamond, 1994; de Heering et al., 2007; Freire & Lee, 2001; McKone & Boyer, 2006; Mondloch et al., 2007; Pellicano & Rhodes, 2003; Tanaka et al.,

1998) but is not adult-like in others (e.g., Freire & Lee, 2001; Mondloch et al., 2002; Mondloch & Thomson, 2008). Our results suggest that such variable performance on different face processing tasks may be because children's sensitivity to facial coding dimensions is not fully adult-like (Rhodes et al., 2005), although even young children are capable of relying on norm-based coding.

While we were in the process of completing this manuscript, Jeffery et al. (in press) demonstrated that 4- to 6-year-old children exhibit evidence for the use of norm-based face coding. In their study, both adults and 4- to 6-year-old children were asked to indicate whether a series of faces of varying degrees of distortion (0%, ±20%, ±40%) were compressed or expanded both before and after an adaptation phase in which they were shown extremely distorted faces (half of participants viewed +50% expanded faces, while the other half viewed -50% compressed faces). Both age groups exhibited comparable simple aftereffects and in a follow-up study, experienced larger simple aftereffects when the adapting stimuli were distant from the face prototype than when they were near. Collectively, the results of Jeffery et al. and our own work suggest that 5-year-old children utilize norm-based coding in a manner comparable to adults and rely on a face prototype that is continuously updated by experience. Thus children's poor performance on certain face processing tasks (e.g., detecting differences in the spacing of features) cannot be attributed to a reliance on a face prototype that is qualitatively different than that of adults.

Race of face. Similar to adults, 5-year-old children exhibited evidence for race-contingent opposing aftereffects; however, the effect was driven largely by adaptation to Caucasian faces. Like adults, 5-year-olds showed no evidence for simple aftereffects for

Chinese faces. The absence of simple aftereffects for Chinese faces in adult participants may be explained in terms of adults' limited experience with children's faces (especially other-race children's faces). However, because 5-year-olds have a great deal of experience with children's faces, the absence of simple aftereffects for Chinese faces is likely a result of young children's lack of familiarity with other-race faces. Because 8-year-olds showed simple aftereffects for Chinese children's faces, the discrepant pattern of results between 5- and 8-year-olds suggests that between 5 and 8 years of age, children develop an increasingly refined face space with regard to race.

Two potential models may describe the organization of 5-year-olds' face space with respect to race. As shown in Figure 7a, the first model proposes that 5-year-old children possess both a Caucasian and a Chinese prototype; however, relative to the Caucasian prototype, the Chinese prototype is weakly defined because of a lack of experience with other-race faces. Because of such limited experience with other-race faces, there is a great deal of overlap between the coding dimensions used for Caucasian faces and the coding dimensions used for Chinese faces. According to this model, any shift in the Chinese prototype following adaptation to distorted Chinese faces would be cancelled by generalization from adaptation to oppositely distorted Caucasian faces. The second model (depicted in Figure 7b) proposes that 5-year-olds possess a highly specified Caucasian face prototype but have not yet formed a Chinese face prototype because of a lack of experience with other-race faces. Because they have not yet formed a Chinese prototype, 5-year-olds instead encode Chinese faces at an individual level and thus no shift in their prototype occurs following adaptation to distorted Chinese faces.

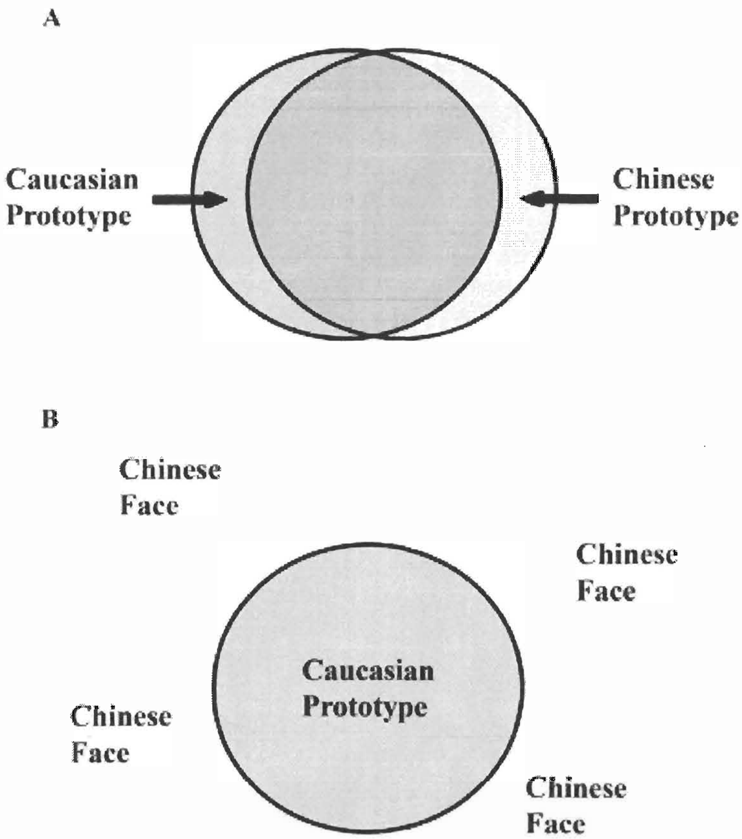

Figure 7. Two models depicting the potential organization of 5-year-olds' face space with regard to race. A. 5-year-olds may possess both a Caucasian and a Chinese face prototype; however, the Chinese prototype is weakly defined relative to the Caucasian prototype. B. 5-year-olds may possess a Caucasian face prototype but have not yet formed a Chinese prototype.

The validity of these two models will be examined in future research. To determine whether 5-year-old children have a Chinese face prototype (or can rapidly form one in the lab), we will test 5-year-olds using a simple aftereffects paradigm in which children are read a storybook comprised of Chinese test and adapting faces only. If children demonstrate evidence for simple attractiveness aftereffects for Chinese faces, this would support the model proposed in Figure 7a and suggest that 5-year-olds have a Chinese face prototype that is simply weakly defined relative to the Caucasian prototype. To determine the degree of overlap between the Caucasian and Chinese face representations in 5-year-olds, we will examine the extent to which adaptation to distorted Caucasian faces generalizes to Chinese faces in 5-year-olds, 8-year-olds, and adults. Participants will judge both Caucasian and Chinese faces pre- and post-adaptation but during the adaptation phase they will be adapted only to distorted Caucasian faces. If the greatest transfer of simple aftereffects from Caucasian to Chinese faces occurs for 5-year-olds, this would suggest that the degree of overlap for the two face prototypes is larger for young children than for adults.

Although the precise mechanism by which the development of face space occurs is yet unknown, it may be attributable to increased experience with faces from different face categories or to general increases in sensitivity to the dimensions on which faces vary. Experience with other-race faces may also lead to the formation of a meaningful social category for own- and other-race faces. Recent research has demonstrated that physical differences in the absence of a social categorical distinction are not sufficient to elicit opposing face aftereffects (Bestelmeyer et al., 2008; Jaquet et al., 2007). Such results may potentially account for the absence of simple aftereffects for Chinese faces in

5-year-olds; although the Caucasian and Chinese faces differed greatly in terms of physical appearance, the social category may not have been meaningful to young children. It was this potential explanation that led us to measure opposing aftereffects for boy versus girl faces. Future research should also investigate whether Caucasian 5-year-olds with ample exposure to both Caucasian and Chinese faces (e.g., children raised in a culturally diverse urban environment) exhibit a different pattern of results than children raised in a predominantly Caucasian environment. It may be the case that frequent exposure to other-race faces increases the salience and meaningfulness of race as a face category and fosters the development of race-specific face prototypes even in very young children.

Our finding that opposing aftereffects were driven by simple aftereffects for Caucasian faces in 5-year-olds is consistent with previous studies showing an own-race recognition advantage in children (Chance et al., 1982; Sangrigoli & de Schonen, 2004a). In fact, both of our proposed models provide an explanation for why young children show an other-race effect despite relying on a face space that is not yet organized in a manner comparable to adults and older children. In both models, children attempt to apply the Caucasian prototype and its corresponding coding dimensions to other-race faces. Because the dimensions that differentiate Chinese faces are likely to differ compared to those that differentiate Caucasian faces, children's recognition accuracy for other-race faces will be reduced relative to own-race faces. Thus our pattern of results serve to supplement the existing literature on the other-race effect in children.

Sex of face. Five-year-olds may not have demonstrated evidence for simple aftereffects for both Caucasian and Chinese faces because they did not perceive race to be a meaningful face category—a criterion for opposing aftereffects in adults (Bestelmeyer et al., 2008; Jaquet et al., 2007). In order to test young children under the conditions in which they would be most likely to demonstrate opposing aftereffects, we adapted 5-year-old children to male and female faces distorted in opposite directions. Sex is an exceptionally meaningful social category for young children (Maccoby, 2002) and children expect sex-related behaviors and traits to be highly stable over time (Rhodes & Gelman, 2008). Because of the high salience of sex as a face category, we would expect that 5-year-olds would be most likely to demonstrate evidence for opposing aftereffects for sex of face as compared to other, less meaningful face categories in the environment. We thus hypothesized that similar to adults (Jaquet & Rhodes, 2008; Little et al., 2005), 5-year-olds would exhibit evidence for sex-contingent opposing aftereffects.

Contrary to our hypothesis, 5-year-olds demonstrated no evidence for sex-contingent opposing face aftereffects. Furthermore, unlike the simple aftereffects observed for Caucasian faces in Experiment 4a, there was no evidence for simple aftereffects for either male or female faces. These results suggest that 5-year-old children reference a single face prototype for both male and female child faces. The aftereffects generated by simultaneous adaptation to male and female faces distorted in opposite directions essentially cancelled each other out, as one would expect if faces belonging to a single face category were distorted in opposite directions (Bestelmeyer et al., 2008; Jaquet et al., 2007).

The results of Experiment 4b suggest that children initially code both male and female faces in reference to a single face prototype that gradually differentiates over time. This process of differentiation can be depicted as a single face space gradually separating into two partially overlapping spaces with separate prototypes that represent male and female faces. Unlike race, children presumably have equal levels of experience with male and female faces, suggesting that differential exposure alone cannot account for the lack of sex-contingent opposing aftereffects in 5-year-olds. Thus although 5-year-olds utilize norm-based coding (Experiment 3), they may rely on fewer dimensions in face space than 8-year-olds and adults and/or be less sensitive to differences within the dimensions of face space (Rhodes et al., 2005). Only with development and increased sensitivity to the dimensions of face space might children begin to utilize dissociable face prototypes with regard to sex.

A potential alternative explanation may account for our failure to find evidence for sex-contingent opposing aftereffects in 5-year-olds. In the current study, we used 4- to 6-year-old children's faces as both test and adapting stimuli. Male and female faces do not structurally diverge until puberty (Farkas, 1988), a time during which testosterone stimulates the growth of the jaw, brow ridges, and facial hair (Verdonck, Gaethofs, Carels, & de Zegher, 1999). Moreover, the development of such traits is inhibited in females by estrogen, which also serves to increase the size of the lips (Thornhill & Møller, 1997). The fact that adult faces are more sexually dimorphic than child faces is consistent with the finding that both adults and children are more accurate identifying the gender of adult faces than child faces (Wild et al., 2000). Due to a lack of sexual dimorphism, it may be that our participants were only able to distinguish male from female faces based on hair cues; all the male stimulus faces had short hair, while the female stimulus faces had long hair styled in a prototypical feminine fashion. Young children are exceptionally rigid in their thinking about gender (Martin & Halverson, 1981); in the preschool years children recognize that sex is stable over time yet they rely strongly on external cues and attributes to determine an individual's sex (De Lisi & Gallagher, 1991; Munroe, Shimmin, & Munroe, 1984). Thus the salient hair cues provided by the face stimuli in our study most likely served to strongly differentiate the male and female faces and ensured that children were visibly aware of the sex distinction. Nonetheless, individual male and female children's faces may not consistently differ from one another in the absence of hair cues. Future research should thus investigate both whether adults tested with children's faces demonstrate evidence for sex-contingent opposing aftereffects and whether children tested with adults' faces exhibit evidence for opposing aftereffects. It may be that both salience of social category (present for sex, absent for race in 5-year-olds) and physiognomic differences (present for race, absent for sex in 5-year-olds) are necessary in order to elicit category-contingent opposing aftereffects.

Contrary to the present finding, past research has demonstrated that infants as young as 3 months of age display a preference for an averaged female child's face over an averaged male child's face, suggesting that infants possess sex-specific face prototypes for children's faces (Quinn et al., in press). We note, however, that the children's faces in that study were older (age 7 to 10 years) than the children's faces used in the current study and hence may have been more sexually dimorphic. Furthermore, we note that the height of the eye fissure in the averaged female face used by Quinn et al. was almost twice as large as that of the eye fissure in the averaged male face. Thus, infants' preference for the averaged female face may simply reflect their visual preference for large eyes (Geldart, Maurer, & Carney, 1999) and does not run counter to our failure to find sex-contingent opposing aftereffects in 5-year-olds.

There are several strengths to the current series of studies. This is the first study to employ the use of children's faces as both test and adapting stimuli. Although the use of children's faces prevented us from directly examining whether 5-year-olds demonstrate evidence for sex-contingent opposing aftereffects under the same conditions as adults and warrants further investigation, it allowed us to test children with faces with which they have the greatest amount of experience. Thus in the race-contingent opposing aftereffects experiment, children could readily identify with and perceive the Caucasian face stimuli as members of their social in-group; had we used adult faces, our child participants may have perceived all of the faces (both Chinese and Caucasian) as out-group members by virtue of their status as adults. Furthermore, our use of children's faces raised interesting questions about the organization of adults' face space with regard to different categories of children's faces (e.g., male/female, Caucasian/Chinese).

A second strength of our investigation is that the method used to measure opposing aftereffects was refined for each age group in order to provide participants with the maximum opportunity to demonstrate opposing aftereffects. For each age group, we examined opposing aftereffects with the same procedure that successfully revealed simple attractiveness aftereffects in previous research (adults and 8-year-olds; Anzures et al., 2009) or in the current set of studies (5-year-olds; Experiment 3). The success of this method was confirmed by the fact that all three age groups showed simple aftereffects for Caucasian faces in each of the opposing aftereffects studies. Thus we can be confident that the presence or absence of opposing aftereffects is reflective of the underlying ability being examined and is not simply the result of our method being inappropriate for the age group tested.

Summary

The present series of experiments made three novel contributions to the literature. First, we provided the first evidence that children as young as 5 exhibit simple attractiveness aftereffects. Along with the results of Jeffery et al. (in press), the current work suggests that norm-based coding is present by 5 years of age. Second, we demonstrated that 8-year-olds exhibit evidence for race-specific face prototypes and that such prototypes begin to emerge as early as 5 years of age. Evidence for race-contingent opposing aftereffects in both 5- and 8-year-olds suggests that young children's limitations on a number of face processing tasks cannot be fully accounted for by a failure to rely on an adult-like face space. While the basic framework for children's face space may parallel that of adults', children require greater distortions in order to detect bizarreness in a face (Anzures et al., 2009) and have difficulty integrating multiple coding dimensions simultaneously (Nishimura et al., 2009). Over time and with improvements in general cognitive and perceptual abilities (Crookes & McKone, 2009; Jeffery et al., in press; Mondloch et al., 2006; Pellicano, Rhodes, & Peters, 2006), children's face space may become increasingly refined and differentiated with respect to both race and sex. Third, our finding of asymmetrical race-contingent aftereffects in adults using children's faces as opposed to previous reports of symmetrical aftereffects with adult faces (Jaquet et al., 2008) suggests that adults' face space may be organized differently for children's faces than for adults' faces. Overall, the results of the present work have a number of implications for the organization of both adults' and young children's face space and highlight several possibilities for future research exploring the development of category-specific face prototypes.

References

Anderson, N. D., & Wilson, H. R. (2005). The nature of synthetic face adaptation. *Vision Research, 45*, 1815-1828.

Anzures, G., Mondloch, C. J., & Lackner, C. (2009). Face adaptation and attractiveness aftereffects in 8-year-olds and adults. *Child Development, 80*(1), 178-191.

Bar-Haim, Y., Ziv, T., Lamy, D., & Hodes, R. M. (2006). Nature and nurture in own-race face processing. *Psychological Science, 17*(2), 159-163.

Barrett, S. E., & O'Toole, A. J. (2009). Face adaptation to gender: Does adaptation transfer across age categories? *Visual Cognition, 17*(5), 700-715.

Bestelmeyer, P. E. G., Jones, B. C., DeBruine, L. M., Little, A. C., Perrett, D. I., Schneider, A., …Conway, C. A. (2008). Sex-contingent face aftereffects depend on perceptual category rather than structural encoding. *Cognition, 107,* 353-365.

Bruce, V., Campbell, R. N., Doherty-Sneddon, G., Import, A., Langton, S., McAuley, S., & Wright, R. (2000). Testing face processing skills in children. *British Journal of Development Psychology, 18*, 319-333.

Carey, S., & Diamond, R. (1994). Are faces perceived as configurations more by adults than by children? *Visual Cognition, 1,* 253-274.

Chance, J. E., Turner, A. L., & Goldstein, A. G. (1982). Development of differential recognition for own- and other-race faces. *Journal of Psychology, 112,* 29-37.

Collishaw, S. M., & Hole, G. J. (2000). Featural and configurational processes in the recognition of faces of different familiarity. *Perception, 29,* 893-909.

Cooper, P. A., Geldart, S. S., Mondloch, C. J., & Maurer, D. (2006). Developmental changes in perceptions of attractiveness: A role of experience? *Developmental Science, 9*(5), 530-543.

Cosmides, L., Tooby, J., & Kurzban, R. (2003). Perceptions of race. *Trends in Cognitive Sciences, 7*(4), 173-179.

Crookes, K., & McKone, E. (2009). Early maturity of face recognition: No childhood development of holistic processing, novel face encoding, or face-space. *Cognition, 111*(2), 219-247.

de Haan, M., Johnson, M., Maurer, D., & Perrett, D. (2001). Recognition of individual faces and average face prototypes by 1- and 3-month-old infants. *Cognitive Development, 16*, 659-678.

de Heering, A., Houthuys, S., & Rossion, B. (2007). Holistic face processing is mature at 4 years of age: Evidence from the composite face effect. *Journal of Experimental Child Psychology, 96,* 57-70.

De Lisi, R., & Gallagher, A. M. (1991). Understanding of gender stability and constancy in Argentinean children. *Merrill-Palmer Quarterly, 37*, 483-502.

Diamond, R., & Carey, S. (1977). Developmental changes in the representation of faces. *Journal of Experimental Child Psychology, 23,* 1-22.

Farkas, L. G. (1988). Age- and sex-related changes in facial proportions. In L. G. Farkas & I. R. Munro (Eds.), *Anthropometric Proportions in Medicine* (pp. 29-56). Springfield, IL: Thomas.

Freire, A., & Lee, K. (2001). Face recognition in 4- to 7-year-olds: Processing of configural, featural, and paraphernalia information. *Journal of Experimental Child Psychology, 80,* 347-371.

Freire, A., Lee, K., & Symons, L. A. (2000). The face-inversion effect as a deficit in the encoding of configural information: Direct evidence. *Perception, 29,* 159-170.

Frisby, J. P. (1980). *Seeing: Illusion, brain and mind.* Oxford, England: Oxford University Press.

Geldart, S., Maurer, D., & Carney, K. (1999). Effects of eye size on adults' aesthetic ratings of faces and 5-month-olds' looking times. *Perception, 28*(3), 361-374.

Gilchrist, A., & McKone, E. (2003). Early maturity of face processing in children: Local and relational distinctiveness effects in 7-year-olds. *Visual Cognition, 10,* 769-793.

Hayden, A., Bhatt, R. S., Zieber, N., & Kangas, A. (2009). Race-based perceptual asymmetries underlying face processing in infancy. *Psychonomic Bulletin & Review, 16*(2), 270-275.

Hering, E. (1964). *Outlines of a theory of the light sense.* Cambridge, MA: Harvard University Press.

Ibbotson, M. R. (2005). Physiological mechanisms of adaptation in the visual system. In C. W. G. Clifford & G. Rhodes (Eds.), *Fitting the mind to the world: Adaptation and after-effects in high-level vision* (pp. 17-45). Oxford, UK: Oxford University Press.

Jaquet, E., & Rhodes, G. (2008). Face aftereffects indicate dissociable, but not distinct, coding of male and female faces. *Journal of Experimental Psychology: Human Perception and Performance, 34*, 101-112.

Jaquet, E., Rhodes, G., & Hayward, W. G. (2007). Opposite aftereffects for Chinese and Caucasian faces are selective for social category information and not just physical face differences. *The Quarterly Journal of Experimental Psychology, 60*(11), 1457-1467.

Jaquet, E., Rhodes, G., & Hayward, W. G. (2008). Race-contingent aftereffects suggest distinct perceptual norms for different race faces. *Visual Cognition, 16*(6), 734-753.

Jeffery, L., McKone, E., Haynes, R., Firth, E., Pellicano, E., & Rhodes, G. (in press). Four- to- six-year-old children use norm-based coding in face space. *Journal of Vision.*

Jeffery, L., Rhodes, G., & Busey, T. (2007). Broadly tuned, view-specific coding of face shape: Opposing figural aftereffects can be induced in different views. *Vision Research, 47*, 3070-3077.

Jiang, F., Blanz, V., & O'Toole, A. J. (2007). The role of familiarity in 3-D view transferability in identity adaptation. *Vision Research, 47*(4), 525-531.

Johnston, R. A., Kanazawa, M., Kato, T., & Oda, M. (1997). Exploring the structure of multidimensional face-space: The effects of age and gender. *Visual Cognition, 4*(1), 39-57.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007). The other-race effect develops during infancy: Evidence of perceptual narrowing. *Psychological Science, 18*(12), 1084-1089.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Gibson, A., Smith, M., …Pascalis, O. (2005). Three-month-olds, but not newborns, prefer own-race faces. *Developmental Science, 8*(6), F31-F36.

Kuefner, D., Macchi Cassia, V., Picozzi, M., Bricolo, E. (2008). Do all kids look alike? Evidence for an other-age effect in adults. *Journal of Experimental Psychology: Human Perception and Performance, 34*(4), 811-817.

Kurzban, R., Tooby, J., & Cosmides, L. (2001). Can race be erased? Coalitional computation and social categorization. *Proceedings of the National Academy of Sciences, 98*(26), 15387-15392.

Langlois, J. H., & Roggman, L. A. (1990). Attractive faces are only average. *Psychological Science, 1*(2), 115-121.

Lee, K., Byatt, G., & Rhodes, G. (2000). Caricature effects, distinctiveness, and identification: Testing the face-space framework. *Psychological Science, 11,* 379-385.

Leopold, D. A., & Bondar, I. (2005). Adaptation to complex visual patterns in humans and monkeys. In C. W. G. Clifford & G. Rhodes (Eds.), *Fitting the mind to the world: Adaptation and after-effects in high-level vision* (pp. 189-211). Oxford, UK: Oxford University Press.

Leopold, D. A., O'Toole, A. J., Vetter, T., & Blanz, V. (2001). Prototype-referenced shape encoding revealed by high-level aftereffects. *Nature Neuroscience, 4(*1), 89-94.

Little, A. C., DeBruine, L. M., & Jones, B. C. (2005). Sex-contingent face after-effects suggest distinct neural populations code male and female faces. *Proceedings of the Royal Society- Biological Sciences, 272*, 2283-2287.

Little, A. C., DeBruine, L. M., Jones, B. C., & Waitt, C. (2008). Category contingent aftereffects for faces of different races, ages and species. *Cognition, 106*, 1537-1547.

Maccoby, E. E. (2002). Gender and group processes. *Current Directions in Psychological Science, 11*, 54-58.

Martin, C. L., & Halverson, C. F., Jr. (1981). A schematic processing model of sex typing and stereotyping in children. *Child Development, 52*, 1119-1134.

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Science, 6,* 255-260.

McKone, E., & Boyer, B. L. (2006). Sensitivity of 4-year-olds to featural and second-order relational changes in face distinctiveness. *Journal of Experimental Child Psychology, 94*, 134-162.

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy and Law, 7,* 3-35.

Mondloch, C. J., Dobson, K. S., Parsons, J., & Maurer, D. (2004). Why 8-year-olds cannot tell the difference between Steve Martin and Paul Newman: Factors contributing to the slow development of sensitivity to the spacing of facial features. *Journal of Experimental Child Psychology, 89*, 159-181.

Mondloch, C. J., Geldart, S., Maurer, D., & Le Grand, R. (2003). Developmental changes in face processing skills. *Journal of Experimental Child Psychology, 86*, 67-84.

Mondloch, C. J., Le Grand, R., & Maurer, D. (2002). Configural face processing develops more slowly than featural face processing. *Perception, 31*, 553-566.

Mondloch, C. J., Maurer, D., & Ahola, S. (2006). Becoming a face expert. *Psychological Science, 17*(11), 930-934.

Mondloch, C. J., Pathman, T., Maurer, D., Le Grand, R., & de Schonen, S. (2007). The composite face effect in six-year-old children: Evidence of adultlike holistic face processing. *Visual Cognition, 15*, 564-577.

Mondloch, C. J., & Thomson, K. (2008). Limitations in four-year-old children's sensitivity to the spacing among facial features. *Child Development, 79*(5), 1513-1523.

Munroe, R. H., Shimmin, H. S., & Munroe, R. L. (1984). Gender understanding and sex role preference in four cultures. *Developmental Psychology, 20*, 673-682.

Nishimura, M., Maurer, D., & Gao, X. (2009). Exploring children's face space: A multidimensional scaling analysis of the mental representation of facial identity. *Journal of Experimental Child Psychology, 103*, 355-375.

Nishimura, M., Maurer, D., Jeffery, L., Pellicano, E., & Rhodes, G. (2008). Fitting the child's mind to the world: Adaptive norm-based coding of facial identity in 8-year-olds. *Developmental Science, 11*(4), 620-627.

Pellicano, E., & Rhodes, G. (2003). Holistic processing of faces in preschool children and adults. *Psychological Science, 14*(6), 618-622.

Pellicano, E., Rhodes, G., & Peters, M. (2006). Are preschoolers sensitive to configural information in faces? *Developmental Science, 9*, 270-277.

Potter, T., & Corneille, O. (2008). Locating attractiveness in the face space: Faces are more attractive when closer to their group prototype. *Psychonomic Bulletin & Review, 15*(3), 615-622.

Quinn, P. C., Conforto, A., Lee, K., O'Toole, A. J., Pascalis, O., & Slater, A. M. (in press). Infant preferences for individual women's faces extends to girl prototype faces. *Infant Behavior and Development*, doi: 10.1016/j.infbeh.2010.03.001

Rhodes, G., Brennan, S., & Carey, S. (1987). Identification and ratings of caricatures: Implications for mental representations of faces. *Cognitive Psychology, 19,* 473-497.

Rhodes, M., & Gelman, S. A. (2008). Categories influence predictions about individual consistency. *Child Development, 79*, 1271-1288.

Rhodes, G., Halberstadt, J., Jeffery, L., & Palermo, R. (2005). The attractiveness of average faces is not a generalized mere exposure effect. *Social Cognition, 23*(3), 205-217.

Rhodes, G., Hayward, W. G., & Winkler, C. (2006). Expert face coding: Configural and component coding of own-race and other-race faces. *Psychonomic Bulletin & Review, 13,* 499-505.

Rhodes, G., & Jeffery, L. (2006). Adaptive norm-based coding of facial identity. *Vision Research, 46,* 2977-2987.

Rhodes, G., Jeffery, L., Watson, T. L., Clifford, C. W. G., & Nakayama, K. (2003). Fitting the mind to the world: Face adaptation and attractiveness aftereffects. *Psychological Science, 14*, 558-566.

Rhodes, G., Jeffery, L., Watson, T. L., Jaquet, E., Winkler, C., & Clifford, C. W. G. (2004). Orientation-contingent face aftereffects and implications for face-coding mechanisms. *Current Biology, 14*, 2119-2123.

Rhodes, G., Robbins, R., Jaquet, E., McKone, E., Jeffery, L., & Clifford, C. W. G. (2005). Adaptation and face perception: How aftereffects implicate norm-based coding of faces. In C. W. G. Clifford & G. Rhodes (Eds.), *Fitting the mind to the world: Adaptation and after-effects in high-level vision* (pp. 213-240). Oxford, UK: Oxford University Press.

Rhodes, G., Sumich, A., & Byatt, G. (1999). Are average facial configurations attractive only because of their symmetry? *Psychological Science, 10,* 52-58.

Rhodes, G., & Tremewan, T. (1994). Understanding face recognition: Caricature effects, inversion, and the homogeneity problem. *Visual Cognition, 1,* 275-311.

Rhodes, G., & Tremewan, T. (1996). Averageness, exaggeration, and facial attractiveness. *Psychological Science, 7*(2), 105-110.

Robbins, R., McKone, E., & Edwards, M. (2007). Aftereffects for face attributes with different natural variability: Adaptor position effects and neural models. *Journal of Experimental Psychology: Human Perception and Performance, 33*(3), 570-592.

Sangrigoli, S., & de Schonen, S. (2004a). Effect of visual experience on face processing: A developmental study of inversion and non-native effects. *Developmental Science, 7*, 74-87.

Sangrigoli, S., & de Schonen, S. (2004b). Recognition of own-race and other-race faces by three-month-old infants. *Journal of Child Psychology and Psychiatry, 45*(7), 1219-1227.

Sangrigoli, S., Pallier, C., Argenti, A. M., Ventureyra, V. A. G., & de Schonen, S. (2006). Reversibility of the other-race effect in face recognition during childhood. *Psychological Science, 16,* 440-444.

Slater, A., Von der Schulenberg, C., Brown, E., Badenoch, M., Butterworth, G., Parsons, S., & Samuels, C. (1998). Newborn infants prefer attractive faces. *Infant Behavior and Development, 21*(2), 345-354.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology, Human Experimental Psychology, 46,* 225-245.

Tanaka, J. W., Kay, J. B., Grinnell, E., Stansfield, B., & Szechter, T. (1998). Face recognition in young children: When the whole is greater than the sum of its parts. *Visual Cognition, 5,* 479-496.

Thornhill, R., & Møller, A. P. (1997). Developmental stability, disease and medicine. *Biological Reviews of the Cambridge Philosophical Society, 72*, 497-548.

Valentine, T. (1991). A unified account of the effects of distinctiveness, inversion, and race in face recognition. *The Quarterly Journal of Experimental Psychology, 43A*(2), 161-204.

Valentine, T., Darling, S., & Donnelly, M. (2004). Why are average faces attractive? The effect of view and averageness on the attractiveness of female faces. *Psychonomic Bulletin and Review, 11,* 482-487.

Verdonck, A., Gaethofs, M., Carels, C., & de Zegher, F. (1999). Effect of low-dose testosterone treatment on craniofacial growth in boys with delayed puberty. *European Journal of Orthodontics, 21*, 137-143.

Vida, M. D., & Mondloch, C. J. (2009). Children's representations of facial expressions and identity: Identity-contingent expression aftereffects. *Journal of Experimental Child Psychology, 104*(3), 326-345.

Webster, M. A. (2004). Pattern selective adaptation in color and form perception. In L. M. Chalupa & J. S. Werner (Eds.), *The visual neurosciences: Vol. 2* (pp. 936-947). Cambridge, MA: MIT Press.

Webster, M. A., Kaping, D., Mizokami, Y., & Dumahel, P. (2004). Adaptation to natural face categories. *Nature, 428*, 558-561.

Webster, M. A., & MacLin, O. H. (1999). Figural aftereffects in the perception of faces. *Psychonomic Bulletin and Review, 6*(4), 647-653.

Wild, H. A., Barrett, S. E., Spence, M., O'Toole, A. J., Cheng, Y., & Brooke, J. (2000). Recognition and sex categorization of adults' and children's faces: Examining performance in the absence of sex stereotyped cues. *Journal of Experimental Child Psychology, 77*, 269-291.

Winkler, C., & Rhodes, G. (2005). Perceptual adaptation affects attractiveness of female bodies. *British Journal of Psychology, 96,* 141-154.

Young, A. W., Hellawell, D., & Hay, D. C. (1987). Configurational information in face perception. *Perception, 16,* 747-759.

Zajonc, R. B. (2001). Mere exposure: A gateway to the subliminal. *Current Directions in Psychological Science, 10,* 224-228.

Appendix 1

Brock University

Research Services 688-5550 ext 3035 reb@brocku.ca fax (905) 688-1748 St. Catharines, Ontario Canada L2S 3A1 Telephone (905)

DATE: **October 04, 2004**

FROM: Linda Rose-Krasnor, Chair
Research Ethics Board (REB)

TO: Cathy MONDLOCH, Psychology
Daphne MAURER, McMaster University

FILE: **04-035 - MONDLOCH**

TITLE: **Development of Visual Processing**

The Brock University Research Ethics Board has reviewed the above research proposal.

DECISION: **Accepted as Clarified**

This project has been approved for the period of **October 04, 2004** to **September 15, 2005** subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The approval may be extended upon request. ***The study may now proceed.***

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and approved by the REB. The Board must approve any modifications before they can be implemented. If you wish to modify your research project, please refer to www.BrockU.CA/researchservices/forms.html to complete the appropriate form ***REB-03 (2001) Request for Clearance of a Revision or Modification to an Ongoing Application.***

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols.

The Tri-Council. Policy Statement requires that ongoing research be monitored. A Final Report is required for all projects, with the exception of undergraduate projects, upon completion of the project. Researchers with projects lasting more than one year are required to submit a Continuing Review Report annually. The Office of Research Services will contact you when this form ***REB-02 (2001) Continuing Review/Final Report*** is required.

Please quote your REB file number on all future

From: Research Ethics Board <reb@brocku.ca>
Subject: **REB 04-035 - MONDLOCH - Continuing Review Accepted**
Date: October 29, 2008 4:03:46 PM EDT
To: "cmondloch@brocku.ca" <cmondloch@brocku.ca>
Cc: "Michelle McGinn" <rebchair@brocku.ca>
1 Attachment, 0.1 KB

FROM: Michelle McGinn, Chair
Research Ethics Board (REB)

TO: Cathy MONDLOCH, Psychology
Daphne Maurer

RE: Continuing Review

FILE: 04-035 - MONDLOCH
Faculty Research
Original clearance date: October 4, 2004
Date of completion: October 31, 2009

DATE: 10/29/2008

Thank you for completing the ***Continuing Review*** form. The Brock University Research Ethics Board has reviewed this report for:

Development of Visual Processing

The Committee finds that your original proposal and ongoing research conforms to the Brock University guidelines set out for ethical research.

*** Continuing Review Accepted.**

MM/en

Research Ethics Office
Brock University
Office of Research Services, MC D250A
500 Glenridge Avenue, St. Catharines, ON L2S 3A1
Phone 905-688-5550 ext. 3035
Fax 905-688-0748
Email: reb@brocku.ca
http://www.brocku.ca/researchservices/Ethics_Safety/Humans/index.php